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FAA-CT-80-41

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DISTANCE MEASURING EQUIPMENT TRAFFIC-LOADING CAPACITY INVESTIGATION

Harold Postel

FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER
Atlantic City Airport, New Jersey 08405



INTERIM REPORT

OCTOBER 1980

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Prepared for
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20590

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| 16. Abstract This phase of the project was performed in response to a letter from Acting Chief, Navigation and Landing Division, ARD-300, dated January 17, 1980, under Project 81, tactical air navigtional aid (TACAN)/distance measuring equipment (DME) Systems Support 042-306 TACAN/DME Maintenance/Sustaining Engineering. The project was performed to determine the cause of loss of DME service at the O'Hare International Airport, Chicago, Illinois, and the Stapleton International Airport very high frequency omnidirectional radio range tactical air navigational system (VORTAC), Denver, Colorado. This report covers the findings of the traffic counts of the O'Hare DME and Stapleton VORTAC. The results show that these systems were being interrogated at rates in excess of the systems' capacities. | | |
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STM

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

When You Know Multiply by To Find

Symbol Symbol

LENGTH

inches
feet
yards
miles

centimeters
meters
kilometers

cm
m
km

AREA

square inches
square feet
square yards
square miles
acres

square centimeters
square meters
square kilometers
hectares

cm²
m²
km²
ha

MASS (weight)

ounces
pounds
short tons
(2000 lb)

grams
kilograms
tonnes

g
kg
t

VOLUME

teaspoons
tablespoons
fluid ounces
cups
pints
quarts
gallons
cubic feet
cubic yards

milliliters
milliliters
milliliters
liters
liters
liters
cubic meters
cubic meters

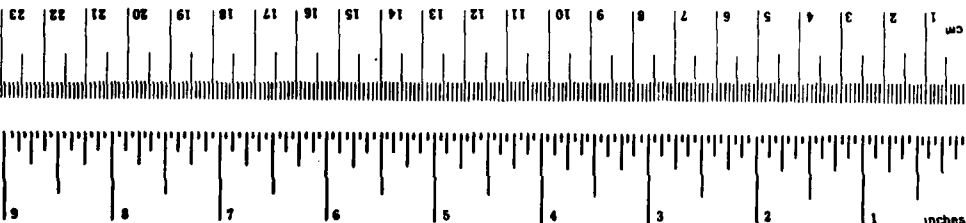
ml
ml
ml
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l
m³
m³

TEMPERATURE (exact)

Fahrenheit temperature
5/9 (after subtracting 32)

Celsius temperature

°C



Approximate Conversions from Metric Measures

When You Know Multiply by To Find

Symbol Symbol

LENGTH

millimeters
centimeters
meters
kilometers

inches
feet
yards
miles

in
ft
yd
mi

AREA

square centimeters
square meters
square kilometers
hectares (10,000 m²)

square inches
square yards
square miles
acres

in²
yd²
mi²

MASS (weight)

grams
kilograms
tonnes (1000 kg)

ounces
pounds
short tons

oz
lb

VOLUME

milliliters
liters
liters
cubic meters
cubic meters

fluid ounces
pints
quarts
gallons
cubic feet
cubic yards

fl oz
pt
qt
gal
ft³
yd³

TEMPERATURE (exact)

Celsius temperature
9/5 (then add 32)

Fahrenheit temperature

°F



*1 in = 2.54 exactly. For other exact conversions and more detailed tables, see NBS Mon. Publ. 780, Units of Weights and Measures, Price \$2.25, SO Catalog No. C13.10.286.

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INTRODUCTION

PURPOSE.

The purpose of this effort was to determine the cause of user complaints of loss of distance measuring equipment (DME) service at O'Hare and Stapleton very high frequency omnidirectional radio range (VOR) DME/tactical air navigation (TACAN). This combined system is known as a VORTAC.

BACKGROUND.

Development of a method for recording the number of distance measuring interrogations to a VORTAC was assigned to the Federal Aviation Administration (FAA) Technical Center in March 1970. Report No. FAA-RD-71-109, dated February 1972, "Investigate and Analyze DME Traffic Load," details the method and approach actually developed for collection of data at VORTAC facilities. The method utilized at both O'Hare and Stapleton was the same. Application of the method is described in the following reports:

FAA-RD-74-93, "Distance Measuring Equipment and Traffic Loading Capacity Investigation," June 1972.

FAA-78-48-LR, "Distance Measuring Equipment Traffic Loading Capacity Investigation, (1977)," July 1978.

FAA-79-4-LR, "Distance Measuring Equipment Traffic Loading Capacity at Key Biscayne, Florida," February 1979.

FAA-79-36-LR, "Distance Measuring Equipment Traffic Loading Capacity Investigation," April 1979.

DESCRIPTION OF EQUIPMENT.

Distance reply signals are supplied by TACAN or DME ground beacon in response to interrogations from an airborne interrogator. Each airborne

interrogator transmits, at the frequency of the radio beacon receiver, a sequence of paired pulses with a random pulse-pair spacing peculiar to itself. These signals are received by the ground-located beacon receiver which will accept, decode, and initiate a reply to as many as 2,700 pulse pairs per second (ppps) without degradation of system performance. At an average interrogation rate per aircraft of 27 per second, this is usually equated to 100 interrogators.

The output of the beacon receiver is controlled by the automatic repetition rate control (ARRC) voltage. The receiver output consists of noise-generated squitter pulses and DME interrogations; the number of squitter pulses varies inversely with the number of interrogations.

TECHNICAL APPROACH.

Tests were conducted to determine the level of traffic loading at both facilities. A graphic computing system utilizing a magnetic tape was programmed to record interrogation rates continuously over a 24-hour period. The program collected 54 samples of data per minute, and then stored the data on the tape. A plot program provided the capability to list and plot the collected data. The test conditions allowed a retriggerable blanking gate to be set at a specific value for the first half of testing and then changed for the final half of the test. The gate width was varied to determine if any change in traffic loading was realized.

TEST CONFIGURATIONS.

The test equipment consisted of a Hewlett-Packard 5328A programmable counter and a Tektronix 4051 graphic computing system with a direct-view-storage cathode ray tube. The graphic system has full American National Standard Code for Information

Interchange (ASCII) character set. A general purpose interface bus and a tape drive consisting of a 3MDC300A cartridge with a capacity of 300K bytes are integral parts of the 4051 graphic system. A Hewlett-Packard 59309AHP-1B digital clock controlled the sampling time of the collected data. The equipment was utilized at each of the two facilities as described below.

1. O'Hare. This facility has installed a Wilcox 596B DME System. The test configuration used at the O'Hare DME site is shown in figure 1. The LOG intermediate frequency (IF) VIDEO OUT, located on the IF sub-assembly 1A2A6, was fed to the Hewlett-Packard 5328A counter A input. The automatic repetition rate control (ARRC) voltage was connected to the voltmeter input of the same counter. The ARRC voltage is a direct current (d.c.) voltage proportional to the interrogation rate that limits the station reply rate to 2,700 ppps. The reference level is adjusted so that the interrogation rate is maintained. As the interrogation rate reaches this level, the ARRC level prevents the system from responding to any further interrogations in excess of 2,700 ppps. This circuit acts as an overload circuit to prevent station shutdown due to over interrogations. A constant pulse repetition frequency (PRF) of 2,700 ppps is maintained, thereby, not allowing any other aircraft to be serviced until such time as the PRF falls below 2,700 ppps.

2. Stapleton. The Stapleton facility is a VORTAC which has installed a RHO-THETA-Navigation (RTN)-2 beacon. The test configuration utilized is shown in figure 2. The IF amplifier video output from the RTN-2 system was connected to the input of the HP-5328A counter A input. Its output, and that of the HP-5309A clock, were connected to the Tektronix 4051 terminal via an IEEE-488 instrumentation bus. Normally, in the RTN-2 radio beacon equipment, the radiofrequency (RF) signal

generator produces simulated interrogation signals which are applied to the transponder at a preset power level via an interrogation overload switch. The number of interrogation responses for the particular power-level setting is used as a measure of receiver sensitivity. The RF signal generator signal, which is set to approximately 45 decibels (dB) lower than the normal interrogation signals, is directed to the receiver sensitivity monitor. When receiver sensitivity is reduced by 1 dB due to high traffic loading, the RF signal generator output is increased to a fixed, preset level by the operation of an interrogation overload relay in the transponder. This prevents an alarm condition.

A modification to prevent false distance lock-on has been installed at this facility (FAA Order AFP 6780.1, chg 224, chapter 229, dated June 30, 1975). When this modification was installed, the interrogation overload circuitry became disabled. Since this modification, a receiver sense alarm would result from an interrogation rate in excess of 5,400 pulse per second (pps), an overload condition. If this condition persisted, the system would shut down and not furnish any DME service.

When the modification was originally installed, the blanking gate portion of this modification was set to 250 microseconds (μ s). The result of this modification was that aircraft interrogations exceeding a specific level will generate an additional blanking period, in this case 250 μ s. The weaker multipath reflected signals following the direct path interrogation will be eliminated, thus preventing a false lock-on. The retriggerable feature of this modification allowed interrogations exceeding the specific level to generate its own reply. At Denver the triggerable level was -80 decibels above 1 milliwatt (dBm). This was determined by procedures outlined in the installation procedures. At this

level (-80 dBm), almost all aircraft tuned to this station within the service volume area would generate gates, lowering the traffic handling capability of the facility because of the 250 μ s blanking period. A revision (AFP 6780.1, chg 298, chapter 263, dated November 1, 1979) was installed on April 30, 1980, and the blanking gate originally set to 250 μ s was reset to 150 μ s and the level that generates this gate was -78 dBm.

The programmable counter utilized at both facilities took fifty-four 1-second video output samples per minute. The test points utilized show all interrogations being received before decoding takes place. At these points a count of 5,400 ppps represents a fully loaded system.

FIELD TEST RESULTS.

The method used to record the traffic count was used at both facilities. Graphic displays of the time of day versus percent of traffic loading are shown in figure 3 for O'Hare and figure 4 for Stapleton. A fully loaded system would be indicated by a count of 5,400 ppps. The percent of loading was calculated by dividing the measured interrogation pulses by 54. The data displayed on the graphs were recorded at the rate of 54 samples per minute, averaged, and then stored on magnetic tape.

O'HARE DME. Data collection started at the O'Hare DME facility on February 13, 1980 and was completed on March 11, 1980. Two actual overload conditions did occur during the data collection period. They occurred on February 19, 1980 at 1602 and 1605 hours. Several other near overload conditions were recorded on February 14, 19, 20, and March 2 and 9, 1980. The total number of departures and arrivals and percent loading for these periods are shown in table 1.

The total number of arrivals and departures were obtained from FAA Form 7200-1, Air Traffic Control Log. The DME is located 400 feet from runway 4L-22R, 1,300 feet from 27R-9L, and 1,200 feet from 14L and 32R (figure 5). Previous tests conducted at the FAA Technical Center has shown that the level of continuous wave (CW) being radiated from various types of airborne interrogators is of a level sufficient to cause receiver sense and reply delay alarm. (See Report No. RD-67-7, "TACAN CW Interference.") The proximity of the site to runway 4L-22R makes this facility susceptible to CW interference when it's in use. In all instances shown in the preceeding table, runway 4L or 22R was in use when the near and overload conditions were recorded.

The arrivals and departures shown in column 2 table 2 represents the actual arrivals and departures for the dates indicated during a 10-hour period. The information was obtained from FAA Form 7200-1. The high and low interrogations rates were obtained over a 24-hour period.

During the first half of the test period, February 13 through February 16, 1980, the blanking gate in the Wilcox 596B DME was set at 0 μ s. It was reset to 150 μ s during the final phase of testing, February 27 through March 11, 1980. This test was performed to determine if any detrimental effect on traffic handling would result from the increased gate width (no significant effect was noted due to gate width change). The range of traffic loading from February 13 through February 26, 1980, was 6 to 64 percent; from February 27 through March 11, 1980, it was 8.5 to 65 percent. To help reduce the traffic loading being experienced by the DME, the Chief, Chicago-O'Hare Air Traffic Control Tower advised air carriers to turn their DME equipment to standby whenever it is not needed.

TABLE 1. RANGE OF TRAFFIC LOADING

| <u>Date</u> <u>(1980)</u> | <u>Time</u> | <u>Figure</u> | <u>Percent</u> <u>Traffic Loading</u> | <u>Total Arrivals</u> <u>and Departures</u> |
|------------------------------|-------------|---------------|--|--|
| 2/14 | 1630 | 4 | 86 | 150 |
| 2/19 | 1602 | 9 | 104 | 152 |
| 2/20 | 1758 | 10 | 88 | 152 |
| 3/2 | 1443 | 20 | 77 | 145 |
| 3/9 | 1043 | 27 | 133 | 146 |

The result of the above memo appears to have decreased the interrogation levels to the DME, and user complaints of lack of DME service beyond 25 nmi. Peak traffic hours at this facility are occurring between 1600 and 1800 hours, the times that the two overload conditions were recorded.

STAPLETON VORTAC. Data collection was started at this facility on April 10 and ended on May 20, 1980. The range of traffic loading, actual arrivals, and departures for the times indicated are shown in table 3. The arrivals and departures were obtained from FAA Form 7200-1, Air Traffic Control Log.

There were 14 occurrences of overload conditions recorded during the test period at this facility. One on April 24, 1980 at 1318 hours resulted in a station shutdown. Table 4 shows the dates, times, and percentage of traffic loading for the overload conditions recorded.

From April 10 through April 26, 1980, the retriggerable blanking was set at 250 μ s as required by AFP 6780.1. Change 298 to this modification required the resetting of this gate to 150 μ s. The range of traffic loading from April 10 to April 26, 1980, as 9.8 to 101 percent; from May 2 to May 20, 1980, was 15 to 98.5 percent.

A memo (similar to the one for O'Hare) has been issued by the United Air Lines

Navigation Aids (NAVAIDS) Manager advising pilots to switch both DME systems to "standby" until just prior to takeoff clearance. The location of the Stapleton VORTAC is shown in figure 6.

The beacon under test was placed into a dummy load to determine if internal receiver noise was contributing to the high interrogation rates. A counter was utilized to count the output of the IF video output. The internal pulse generator was set to various PRF's and the count verified. No extraneous counts were noted. The number of blanking gates that were noted were not inconsistent with the traffic levels recorded. An ongoing program to determine the effects of the retriggerable blanking gate on the RTN-2 TACAN beacon is currently in progress. The results of this program will more readily determine the exact effect on traffic loading. Peak traffic periods are occurring at Stapleton, primarily from 1000 and 1100 hours. Ninety percent of the recorded overload condition occurred between 1000 and 1100 hours.

A test to determine if any outside interference source was the cause of the overload conditions was conducted by ARM-406, at the request of ARM-434. The test was conducted on February 19, 1980, 0900 to 1000 hours, during a peak traffic period. No levels of interference could be found that would result in an overload condition.

TABLE 2. RANGE OF TRAFFIC LOADING, O'HARE

| Range of Traffic Loading Percent | Total Actual Arrivals and Departures | Day of Week | DATE 1980 | Highest Interrogation Rate PPS | Time | Low Interrogation Rate PPS | Time | Figure | µs Blanking Gate Setting |
|----------------------------------|--------------------------------------|--------------------|-----------|--------------------------------|------|----------------------------|------|--------|--------------------------|
| 7-55 | 1638 | Wednesday/Thursday | 2/13, 14 | 3003 | 1855 | 437 | 0435 | 3A | 0 |
| 5-86 | 1606 | Thursday/Friday | 2/14, 15 | 4681 | 1633 | 298 | 2257 | 3B | 0 |
| 7-53 | 1562 | Friday/Saturday | 2/15, 16 | 2868 | 2016 | 424 | 0042 | 3C | 0 |
| 7-51 | 1142 | Saturday/Sunday | 2/16, 17 | 2777 | 1642 | 399 | 2250 | 3D | 0 |
| 7-60 | 1311 | Sunday/Monday | 2/17, 18 | 3263 | 1019 | 356 | 0317 | 3E | 0 |
| 5-61 | 1549 | Monday/Tuesday | 2/18, 19 | 3317 | 1610 | 305 | 0024 | 3F | 0 |
| 7-104 | 1592 | Tuesday/Wednesday | 2/19, 20 | 5664 | 1602 | 340 | 0007 | 3G | 0 |
| 5-88 | 1454 | Wednesday/Thursday | 2/20, 21 | 4771 | 1758 | 225 | 0304 | 3H | 0 |
| 5-59 | 1575 | Thursday/Friday | 2/22, 23 | 3187 | 1712 | 252 | 0006 | 3I | 0 |
| 5-44 | 1337 | Friday/Saturday | 2/23, 24 | 2418 | 1142 | 335 | 2256 | 3J | 0 |
| 5-49 | 1418 | Saturday/Sunday | 2/24, 25 | 2679 | 1534 | 306 | 2244 | 3K | 0 |
| 5-59 | 697 | Sunday/Monday | 2/25, 26 | 3196 | 1748 | 311 | 0149 | 3L | 0 |
| 6-55 | 1569 | Tuesday/Wednesday | 2/26, 27 | 3010 | 1904 | 346 | 0008 | 3M | 150 |
| 5-54 | 1621 | Wednesday/Thursday | 2/27, 28 | 2935 | 1753 | 315 | 0030 | 3N | 150 |
| 9-53 | 1577 | Thursday/Friday | 2/28, 29 | 2878 | 1732 | 499 | 2318 | 3O | 150 |
| 5-61 | 1742 | Friday/Saturday | 2/29, 3/1 | 3383 | 1922 | 309 | 0142 | 3P | 150 |
| 7-47 | 1275 | Saturday/Sunday | 3/1, 2 | 2586 | 1724 | 380 | 2202 | 3Q | 150 |
| 11-77 | 1412 | Sunday/Monday | 3/2, 3 | 4152 | 1443 | 575 | 2251 | 3R | 150 |
| 6-65 | 1572 | Tuesday/Wednesday | 3/4, 5 | 3528 | 1529 | 325 | 0355 | 3S | 150 |
| 5-54 | 1603 | Wednesday/Thursday | 3/5, 6 | 2893 | 1750 | 277 | 0005 | 3T | 150 |
| 6-51 | 1604 | Thursday/Friday | 3/6, 7 | 2773 | 1615 | 433 | 2222 | 3U | 150 |
| 9-133 | 1274 | Friday/Saturday | 3/8, 9 | 7182 | 1043 | 496 | 0240 | 3V | 150 |
| 6-64 | 1428 | Saturday/Sunday | 3/9, 10 | 3437 | 1224 | 313 | 0015 | 3W | 150 |
| 6-67 | 1556 | Sunday/Monday | 3/10, 11 | 3659 | 1954 | 370 | 2235 | 3X | 150 |

TABLE 3. RANGE OF TRAFFIC LOADING

| <u>Date</u> <u>(1980)</u> | <u>Time</u> | <u>Percent</u> <u>Traffic Loading</u> | <u>Total Arrivals</u> <u>and Departures</u> | <u>Figure</u> |
|------------------------------|-------------|--|--|---------------|
| 4/11 | 1012 | 102 | N/A | 56 |
| 4/14 | 1016 | 103 | N/A | 53 |
| 4/18 | 1006 | 111 | 106 | 50 |
| 4/19 | 1011 | 107 | N/A | 49 |
| 4/24 | 1158 | 125 | 96 | 47 |
| 4/25 | 0957 | 102 | 112 | 46 |
| 5/2 | 1828 | 109 | 100 | 42 |
| 5/3 | 1017 | 100 | 104 | 41 |
| 5/4 | 1007 | 110 | 99 | 40 |
| 5/6 | 1104 | 100 | 98 | 38 |
| 5/8 | 1010 | 107 | 80 | 36 |
| 5/12 | 1031 | 103 | 110 | 33 |
| 5/13 | 1009 | 117 | 115 | 32 |

N/A = not available

CONCLUSIONS

Based on the test results, it is concluded that:

1. The data collection samples reflect the current distance measuring equipment (DME) interrogation rates at the facilities tested.
2. The effect of the false DME modification on traffic loading could not be determined during this phase of the testing.
3. The Stapleton very high frequency omnidirectional radio range tactical air navigation (VORTAC) facility is being subjected to overload conditions that have caused station shutdown.
4. User complaints of lack of DME service beyond 25 nautical miles are justified, based on the data collected.
5. The proximity of O'Hare DME to runway 4L-22R does subject it to high levels of continuous wave interference from taxiing aircraft when in use.

6. Both facilities are experiencing interrogation rates in excess of system capacity.

RECOMMENDATIONS

It is recommended that:

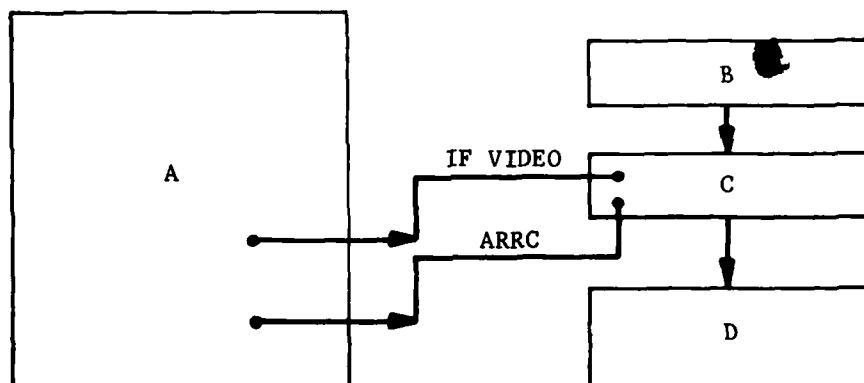
1. A second generation very high frequency omnidirectional radio range tactical air navigation (VORTAC) system be installed at Stapleton as soon as possible.
2. In the interim, one of the instrument landing system distance measuring equipment (ILS/DME) systems currently installed at Stapleton be changed to a terminal omnidirectional radio range distance measuring equipment (TVOR/DME). This should reduce the traffic loading on the Denver VORTAC.
3. Several other VORTAC's in the affected areas be used to provide en route guidance to aircraft utilizing Stapleton and O'Hare Airports as their destination.

TABLE 4. RANGE OF TRAFFIC LOADING, STAPLETON

| Range of Traffic Loading Percent | Total Actual Arrivals and Departures | Day of Week | Date (1980) | Highest Interrogation Rate PPS | Time | Low Interrogation Rate PPS | Time | Figure | μ s Blanking Gate Setting |
|----------------------------------|--------------------------------------|--------------------|-------------|--------------------------------|------|----------------------------|------|--------|-------------------------------|
| 3-115 | N/A | Wednesday/Thursday | 4/9, 10 | 6228 | 1016 | 322 | 1306 | 4A | 250 |
| 9-97 | N/A | Thursday/Friday | 4/10, 11 | 5241 | 0147 | 466 | 0147 | 4B | 250 |
| 10-102 | N/A | Friday/Saturday | 4/11, 12 | 5553 | 1012 | 552 | 0117 | 4C | 250 |
| 15-97 | N/A | Saturday/Sunday | 4/12, 13 | 5247 | 1015 | 810 | 0004 | 4D | 250 |
| 14-94 | N/A | Sunday/Monday | 4/13, 14 | 5094 | 1013 | 766 | 0338 | 4E | 250 |
| 12-103 | N/A | Monday/Tuesday | 4/14, 15 | 5605 | 1016 | 657 | 0318 | 4F | 250 |
| 11-87 | N/A | Tuesday/Wednesday | 4/15, 16 | 4708 | 1901 | 639 | 2344 | 4G | 250 |
| 8-97 | N/A | Wednesday/Thursday | 4/16, 17 | 5232 | 1907 | 458 | 0201 | 4H | 250 |
| 11-111 | 1069 | Friday/Saturday | 4/18, 19 | 6038 | 1006 | 611 | 0119 | 4I | 250 |
| 11-107 | N/A | Saturday/Sunday | 4/19, 20 | 5795 | 1011 | 575 | 2250 | 4J | 250 |
| 9-94 | 1087 | Sunday/Monday | 4/20, 21 | 5049 | 1013 | 461 | 0443 | 4K | 250 |
| 4-125 | 955 | Monday/Tuesday | 4/24, 25 | 6767 | 1158 | 245 | 1144 | 4L | 250 |
| 11-102 | 1041 | Tuesday/Wednesday | 4/25, 26 | 5527 | 0957 | 603 | 0314 | 4M | 250 |
| 10-88 | 827 | Wednesday/Thursday | 4/26, 27 | 4738 | 0824 | 523 | 0519 | 4N | 250 |
| 50-109 | 1136 | Thursday/Friday | 5/2, 3 | 5902 | 1828 | 272 | 1438 | 4O | 250 |
| 17-100 | 913 | Friday/Saturday | 5/3, 4 | 5421 | 1017 | 937 | 2236 | 4P | 250 |
| 14-110 | 933 | Saturday/Sunday | 5/4, 5 | 5987 | 1012 | 809 | 0045 | 4Q | 250 |
| 14-95 | 1082 | Sunday/Monday | 5/5, 6 | 5158 | 1007 | 840 | 0254 | 4R | 250 |
| 12-100 | 1091 | Tuesday/Wednesday | 5/6, 7 | 5403 | 1104 | 685 | 0312 | 4S | 250 |
| 38-92 | 1094 | Wednesday/Thursday | 5/7 | 4979 | 1208 | 2076 | 1632 | 4T | 250 |
| 11-107 | 1052 | Thursday/Friday | 5/8, 9 | 5845 | 1010 | 618 | 0522 | 4U | 250 |
| 14-90 | 1106 | Saturday/Sunday | 5/9, 10 | 4855 | 1154 | 715 | 0621 | 4V | 150 |
| 12-99 | 914 | Sunday/Monday | 5/10, 11 | 5348 | 1026 | 687 | 0456 | 4W | 150 |
| 10-103 | 1013 | Monday/Tuesday | 5/12, 13 | 5587 | 1031 | 542 | 0257 | 4X | 150 |

4. The presence of nearby taxiing aircraft are a possible source of continuous wave interference and should be considered in the location of additional DME systems.

5. Other facilities be retested to provide further inputs as to trends in traffic increase.



A WILCOX 596B DME SYSTEM

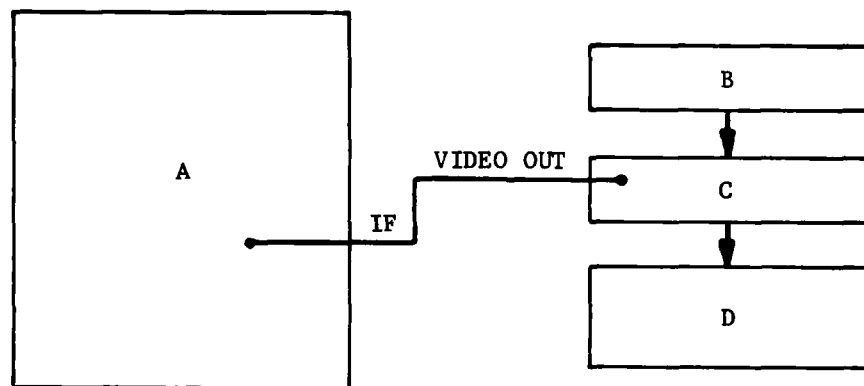
B HEWLETT-PACKARD 59309A HP-IB DIGITAL CLOCK

C HEWLETT-PACKARD 5328A PROGRAMMABLE ELECTRONIC COUNTER

D TEKTRONIX 4051 GRAPHIC COMPUTING SYSTEM

80-41-1

FIGURE 1. CHICAGO (O'HARE) TEST CONFIGURATION



A RTN-2 BEACON

B HEWLETT-PACKARD 59309A HP-IB DIGITAL CLOCK

C HEWLETT-PACKARD 5328A PROGRAMMABLE ELECTRONIC COUNTER

D TEKTRONIC 4051 GRAPHIC COMPUTING SYSTEM

80-41-2

FIGURE 2. DENVER (STAPLETON) TEST CONFIGURATION

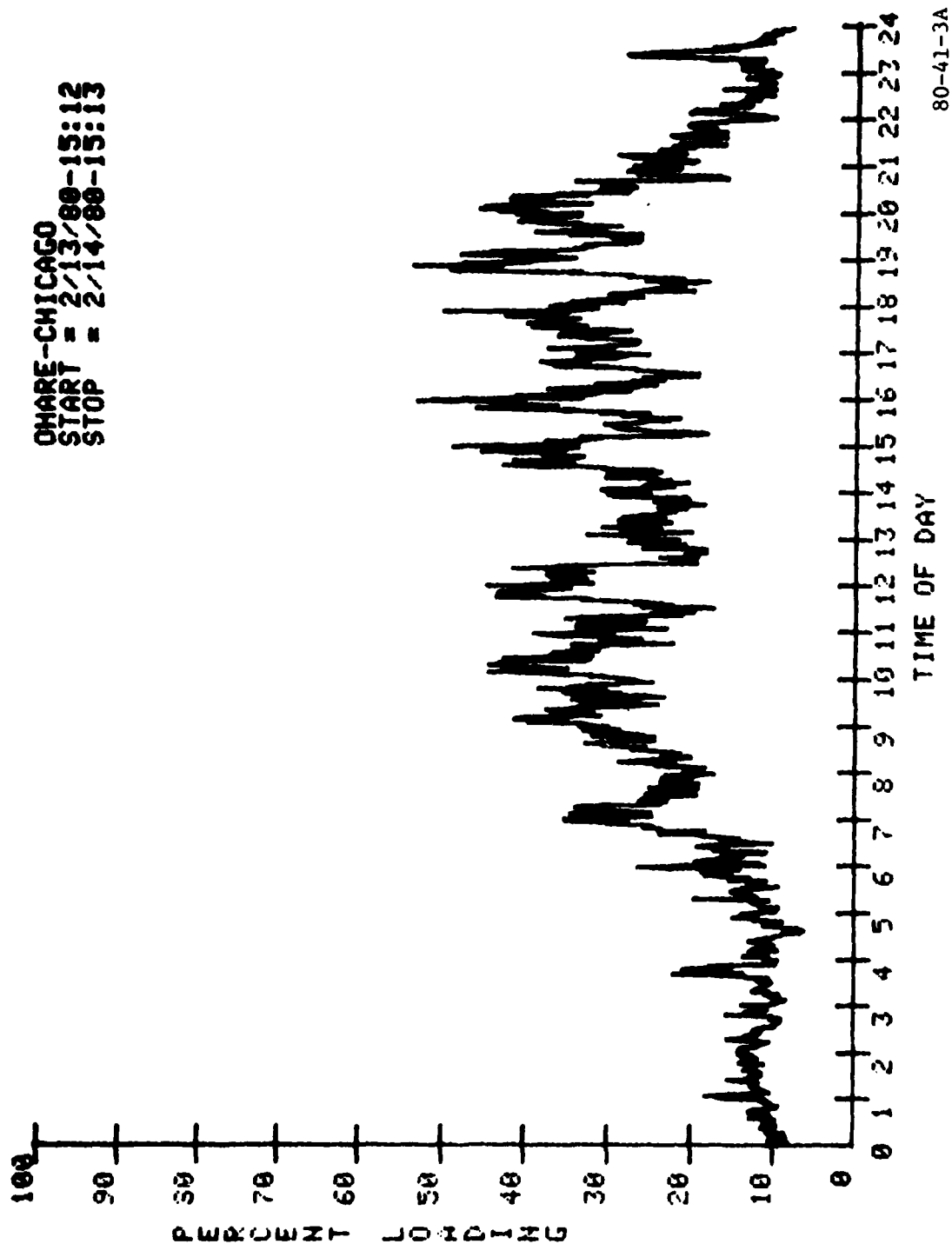


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 1 of 24)

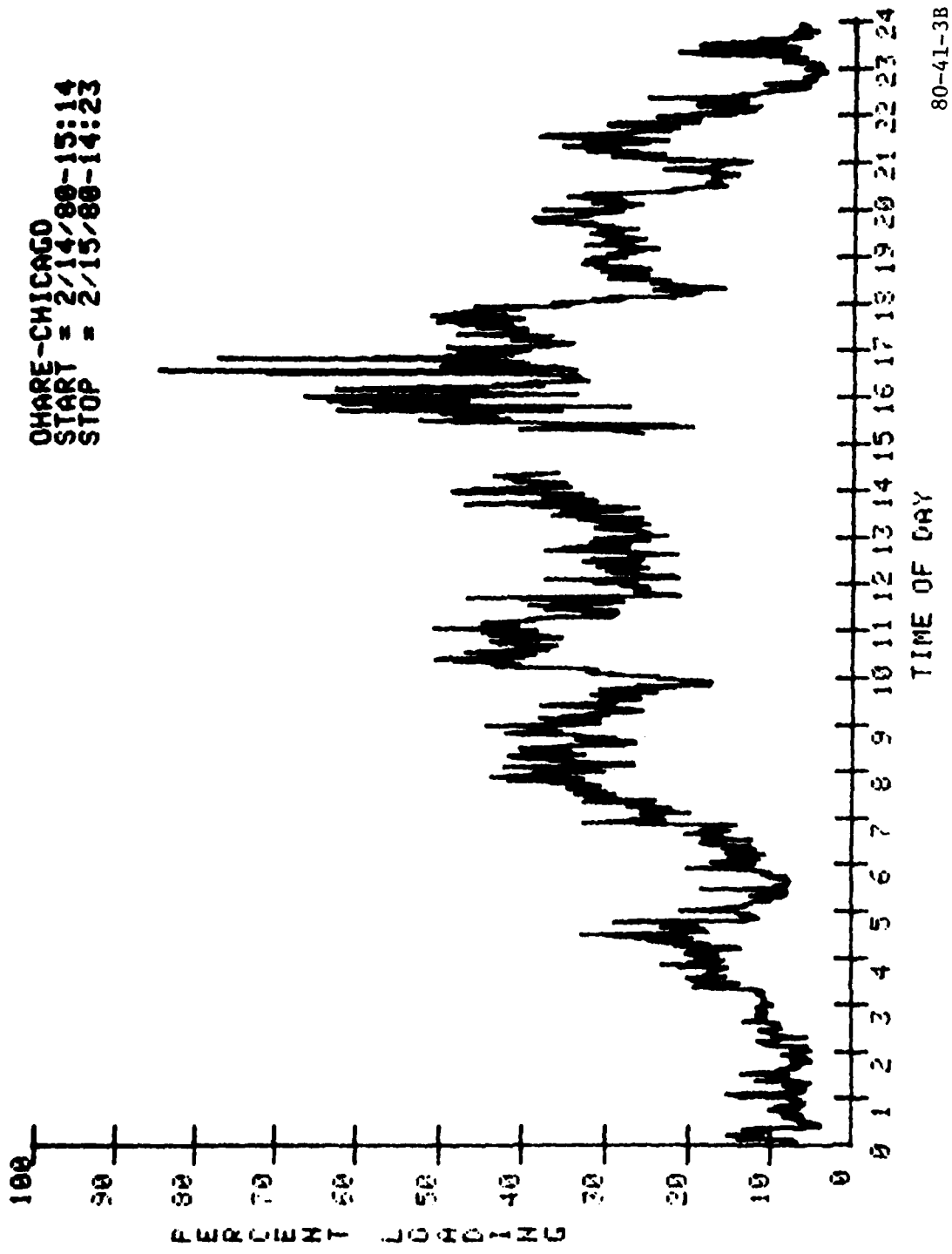


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 2 of 24)

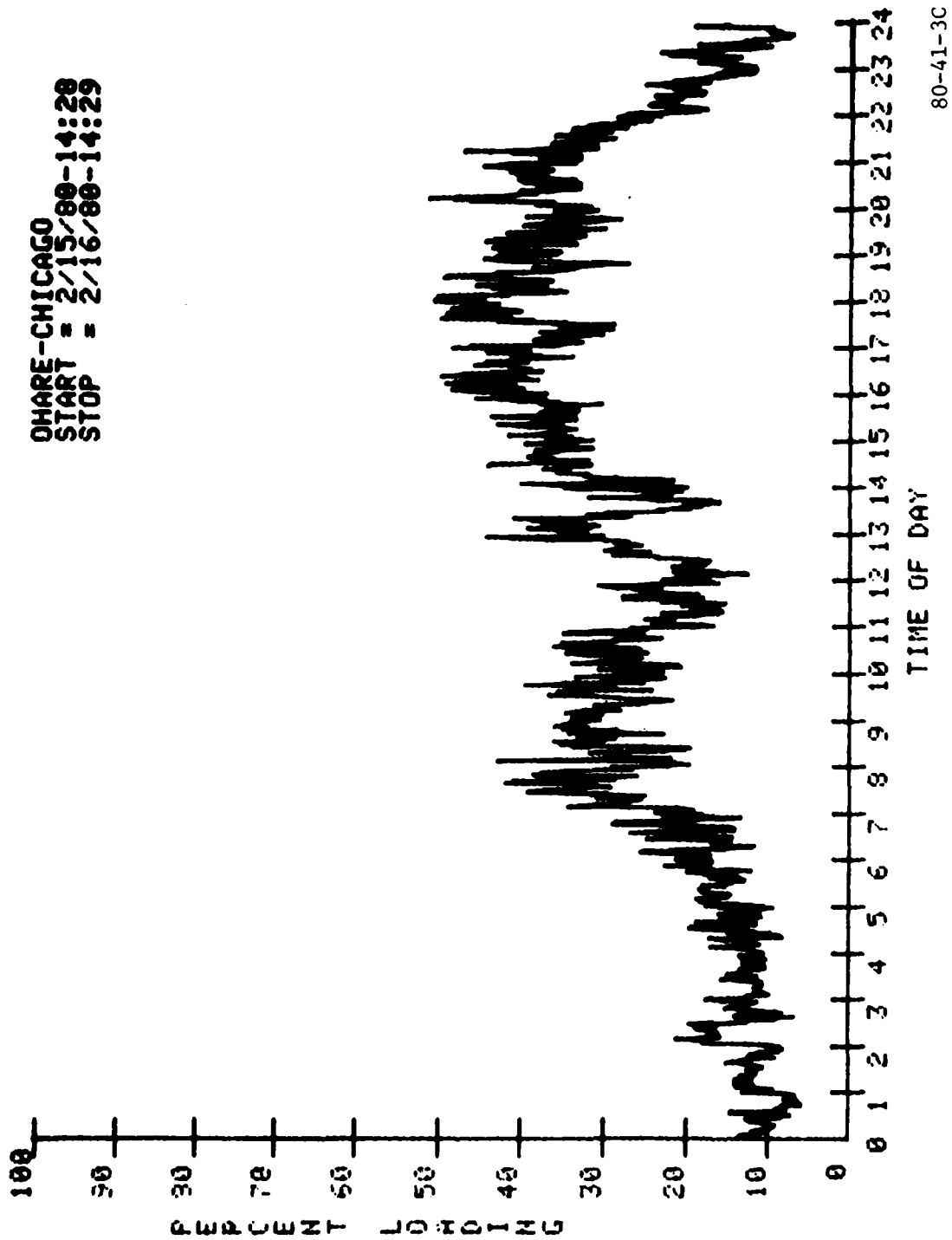


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 3 of 24)

OHARE-CHICAGO
 START = 2/16/80-14:30
 STOP = 2/17/80-14:31

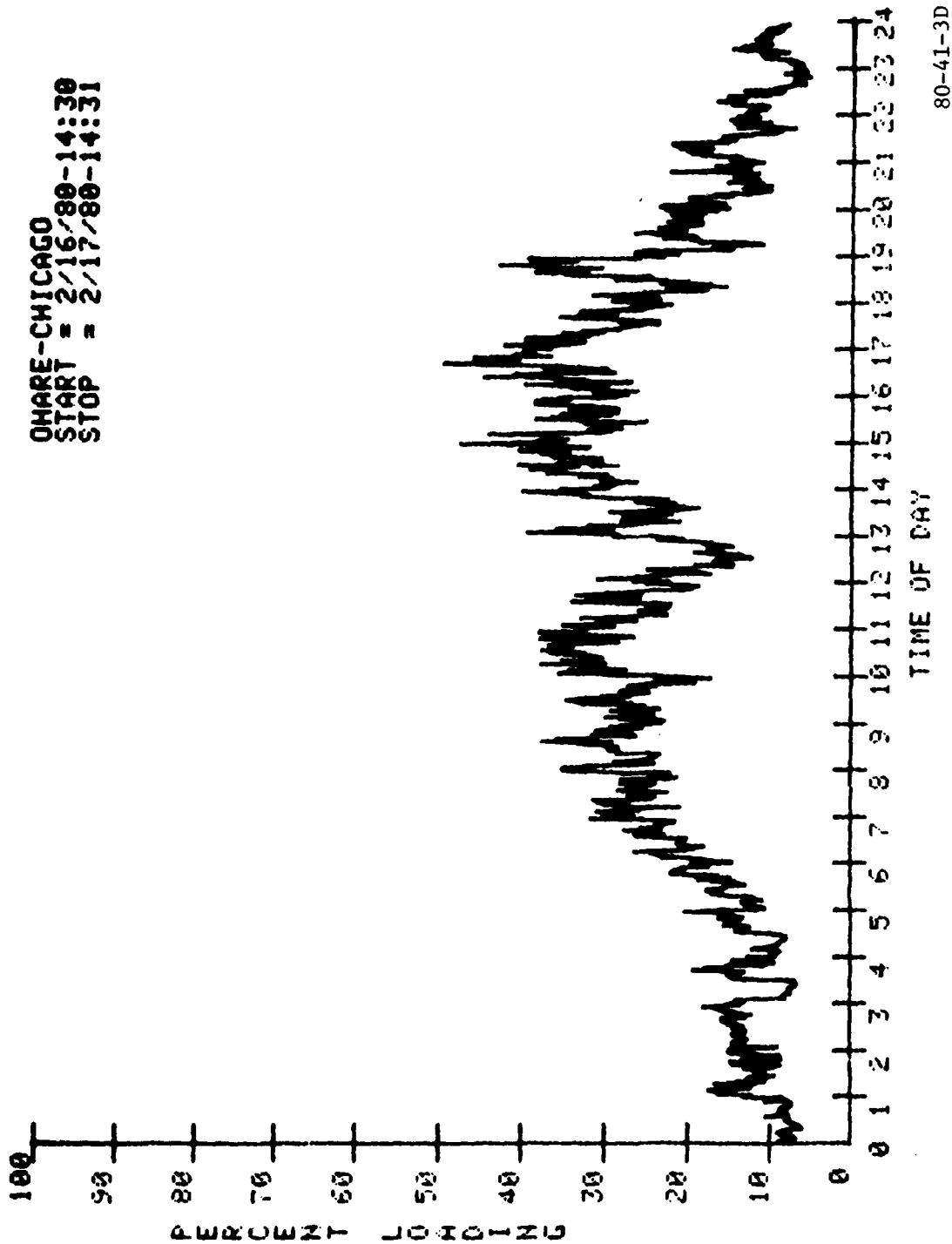


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 4 of 24)

80-41-3D

OHARE-CHICAGO
 START = 2/17/80-14:32
 STOP = 2/18/80-14:33

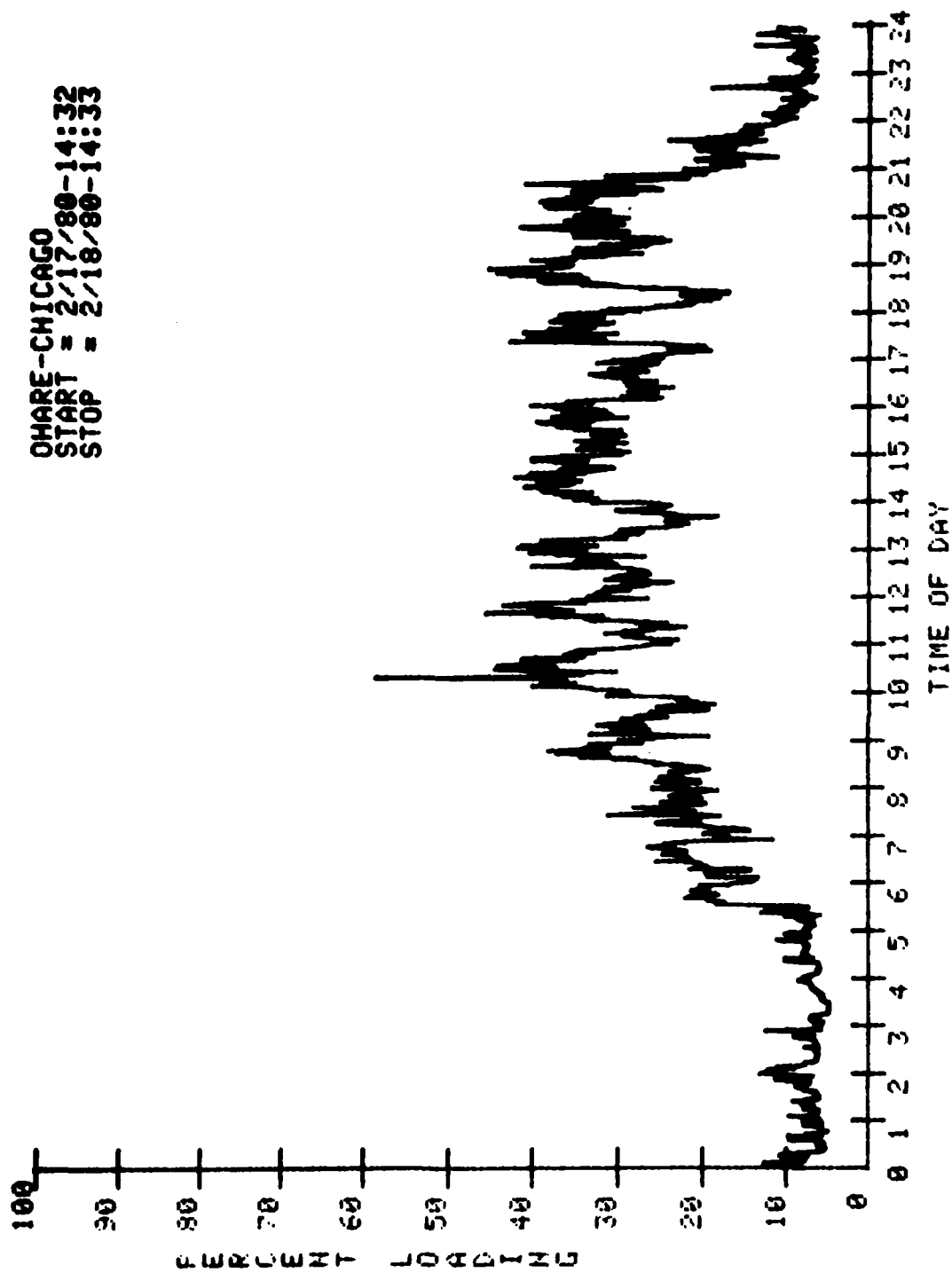


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 5 of 24)

80-41-3E

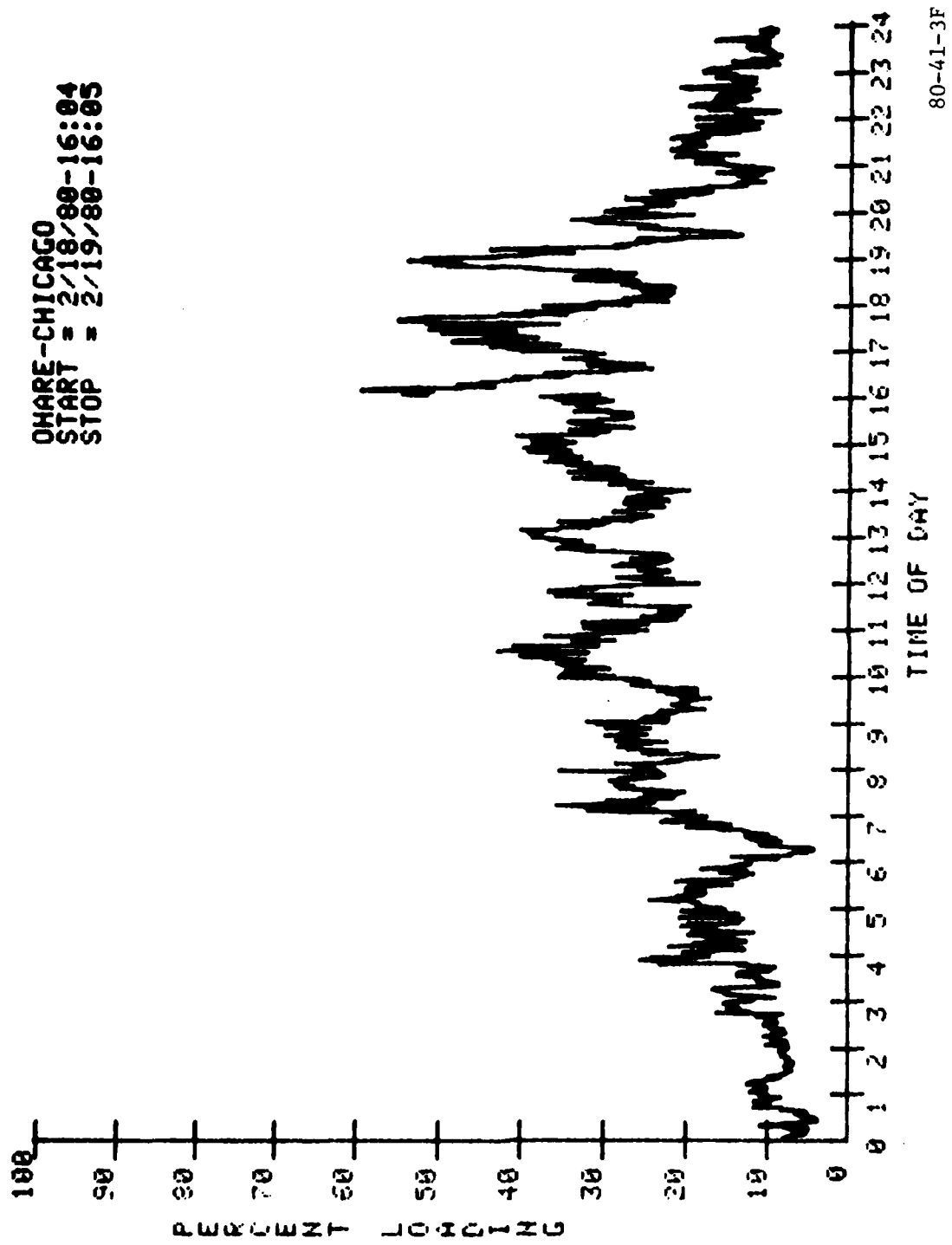


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 6 of 24)

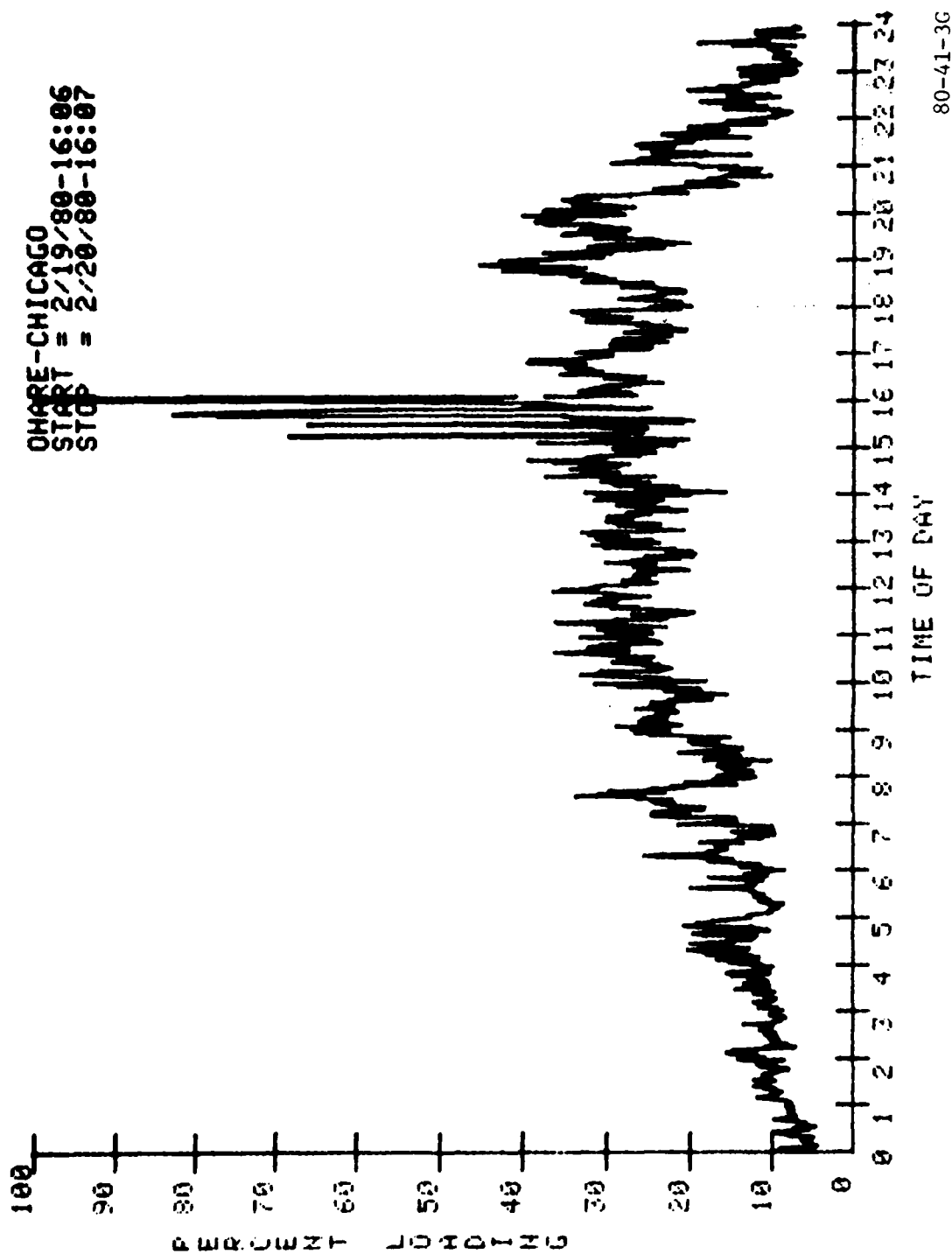


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 7 of 24)

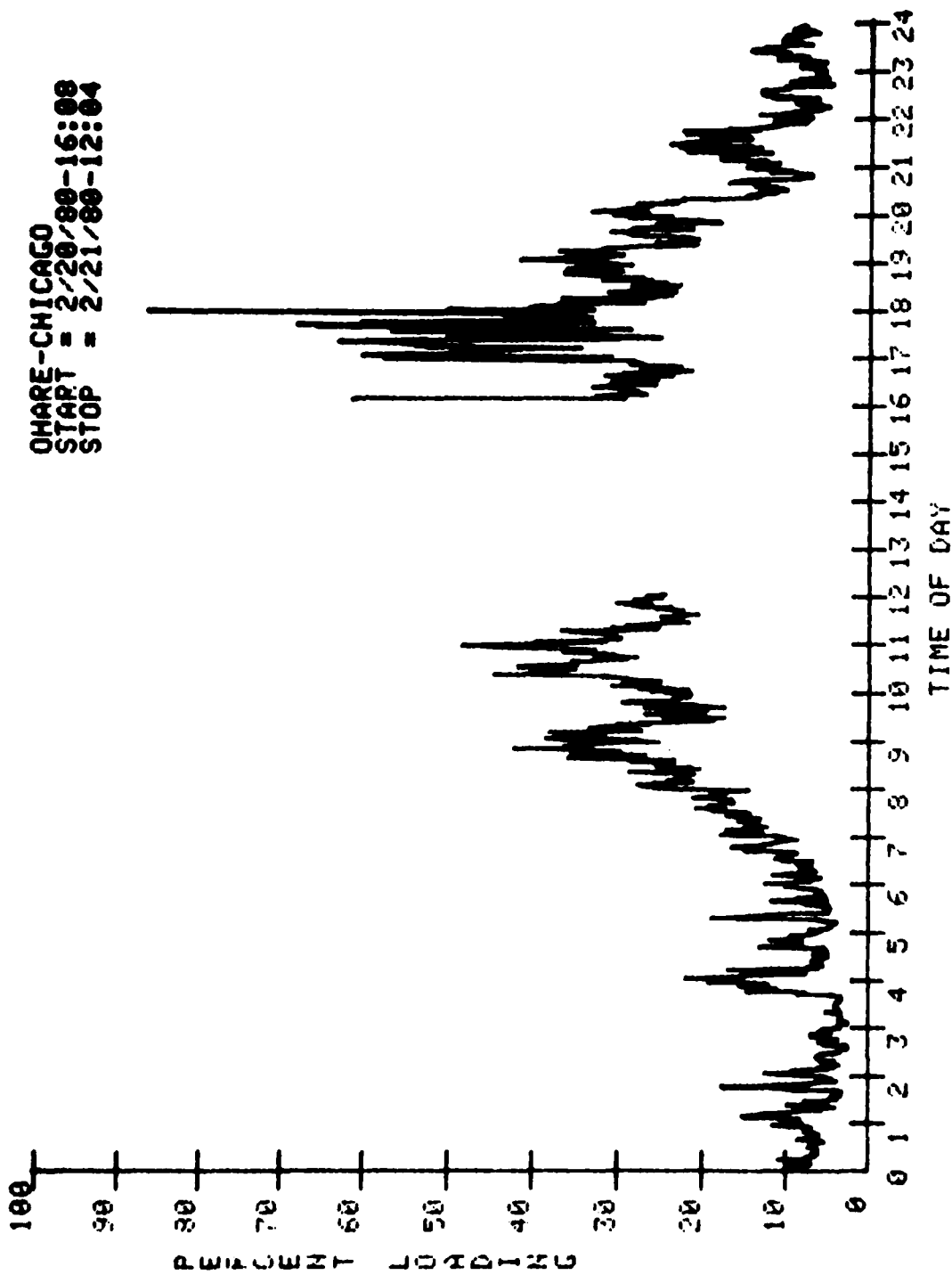
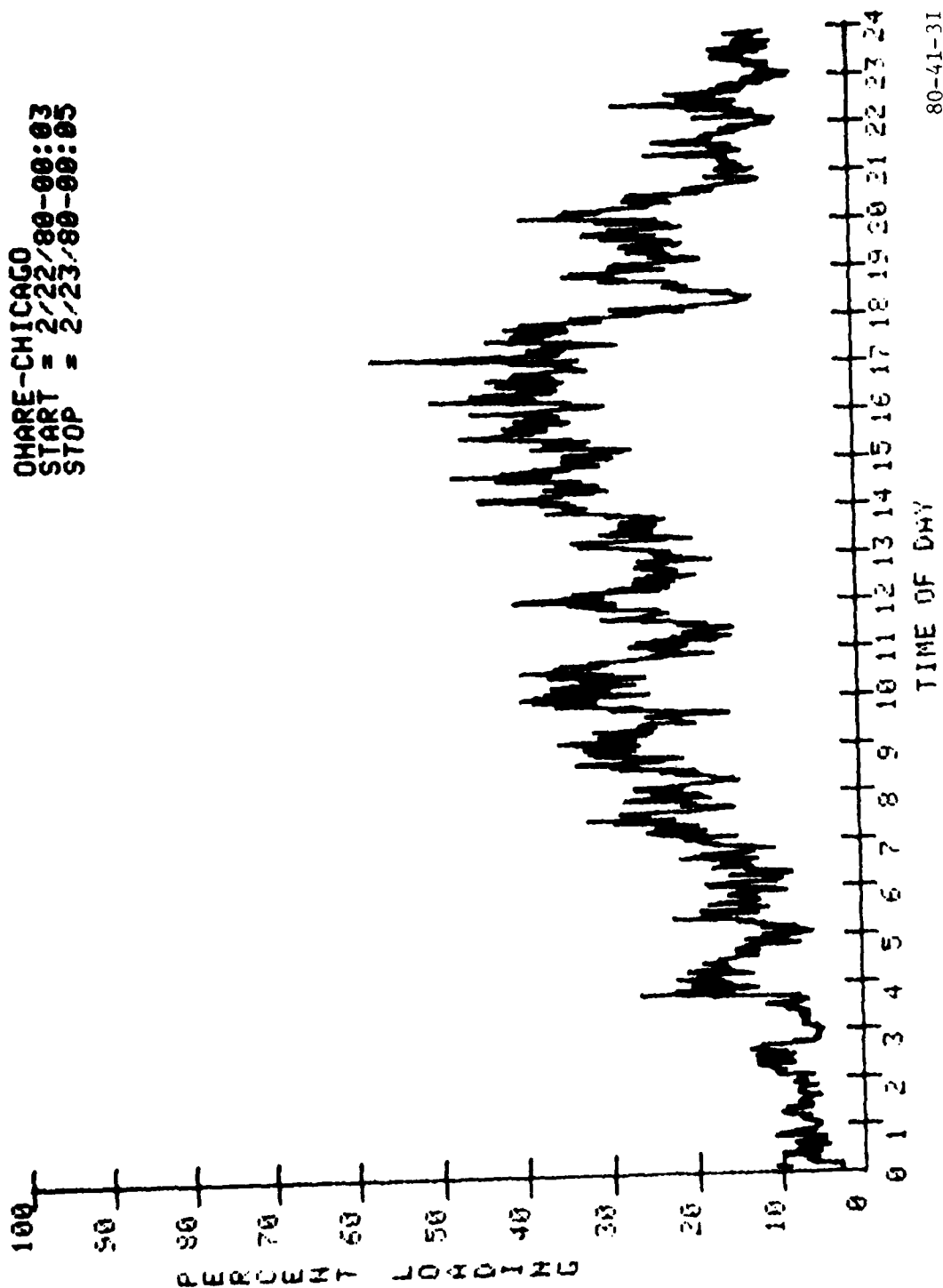


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 8 of 24)

OHARE-CHICAGO
 START = 2/22/80-00:03
 STOP = 2/23/80-00:03



80-41-31

FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 9 of 24)

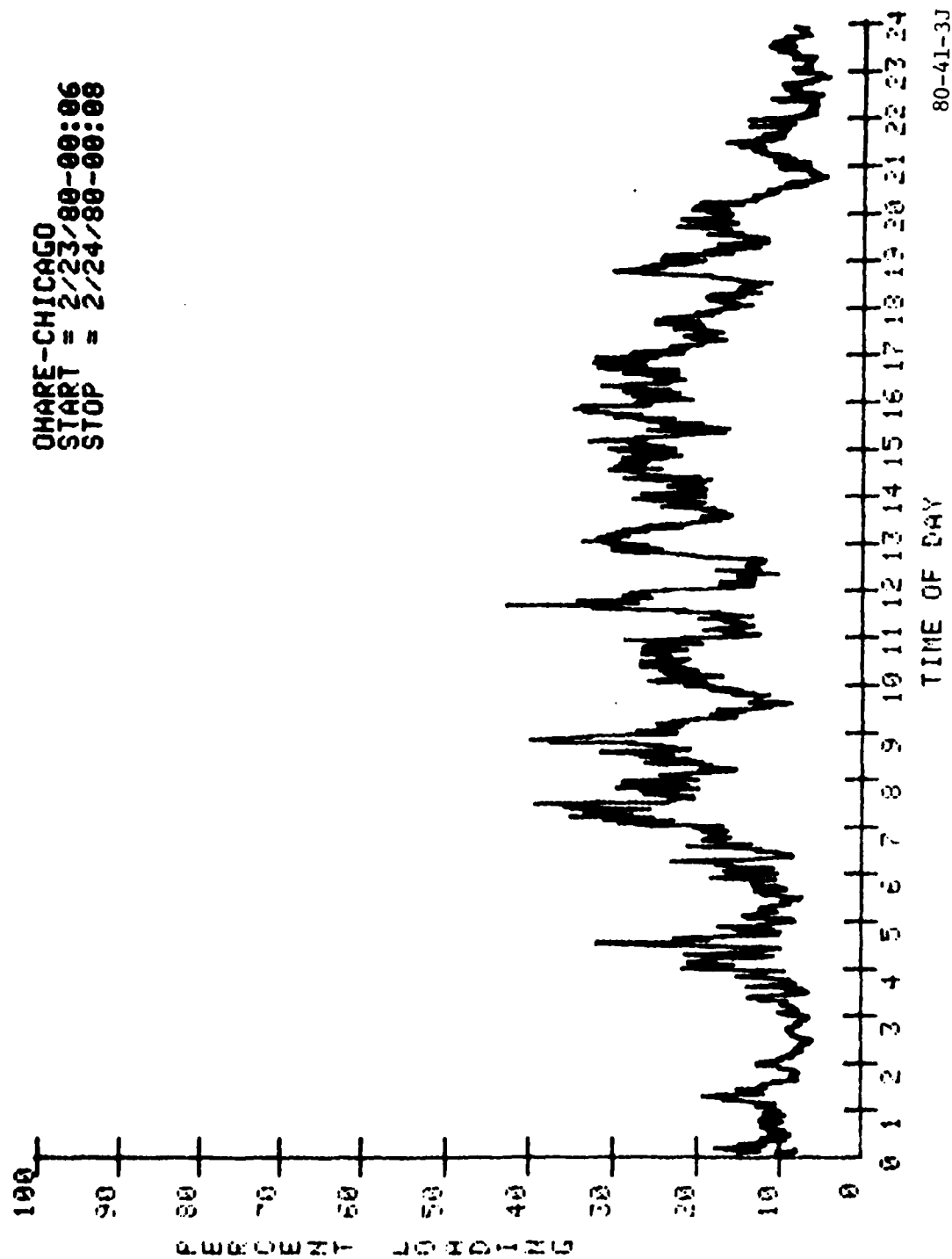


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 10 of 24)

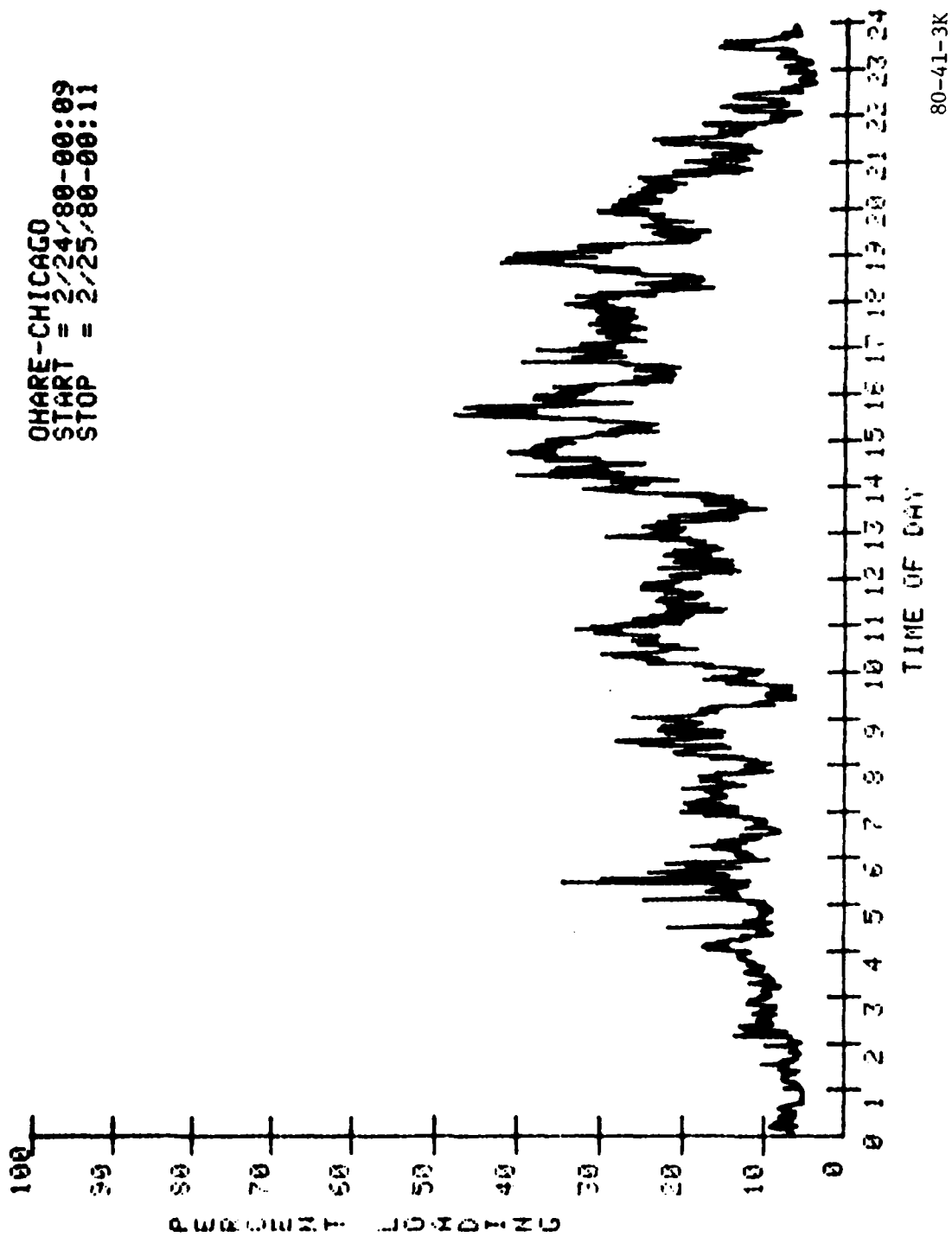


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 11 of 24)

OHARE-CHICAGO
START = 2/25/80-01:32
STOP = 2/26/80-01:33

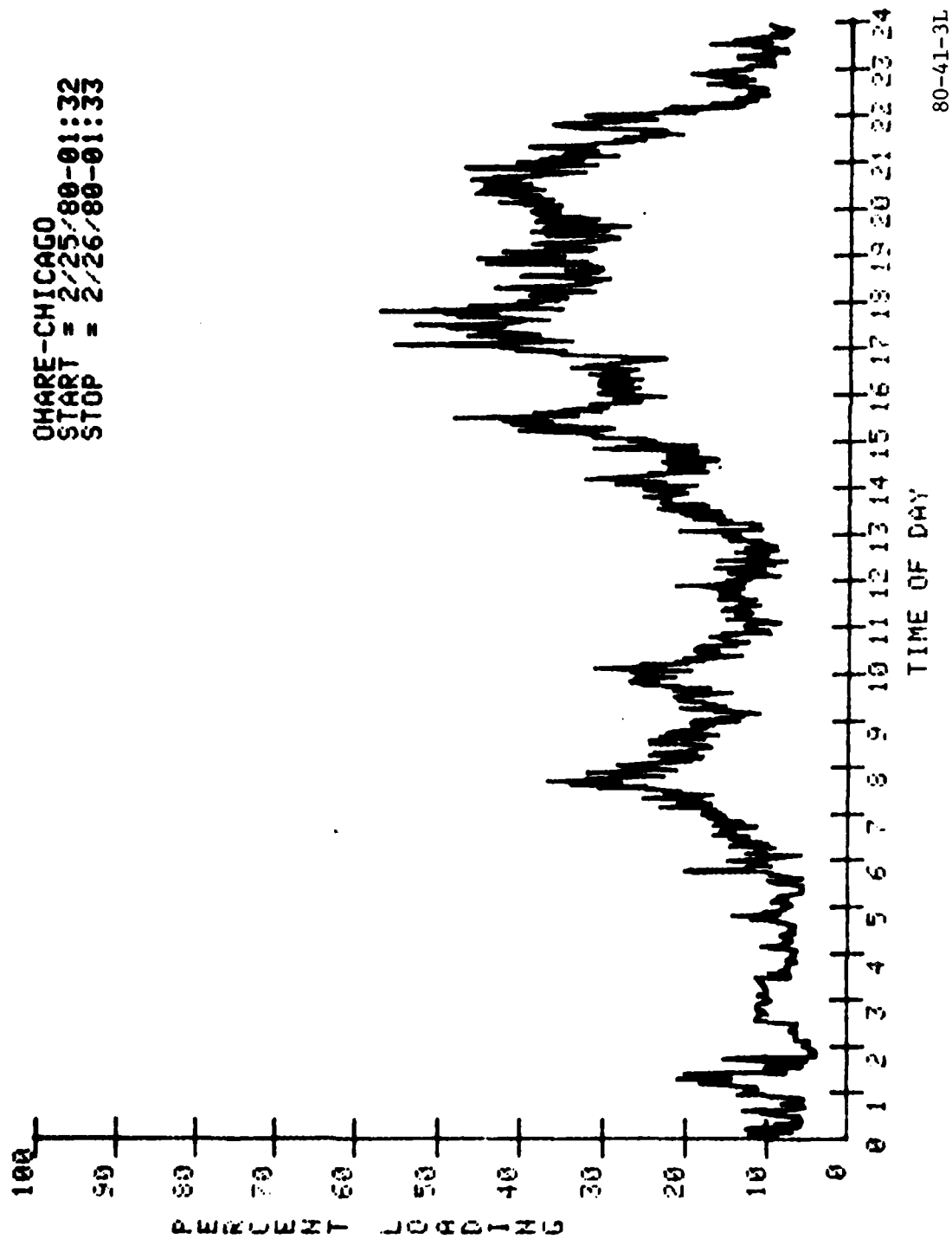


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 12 of 24)

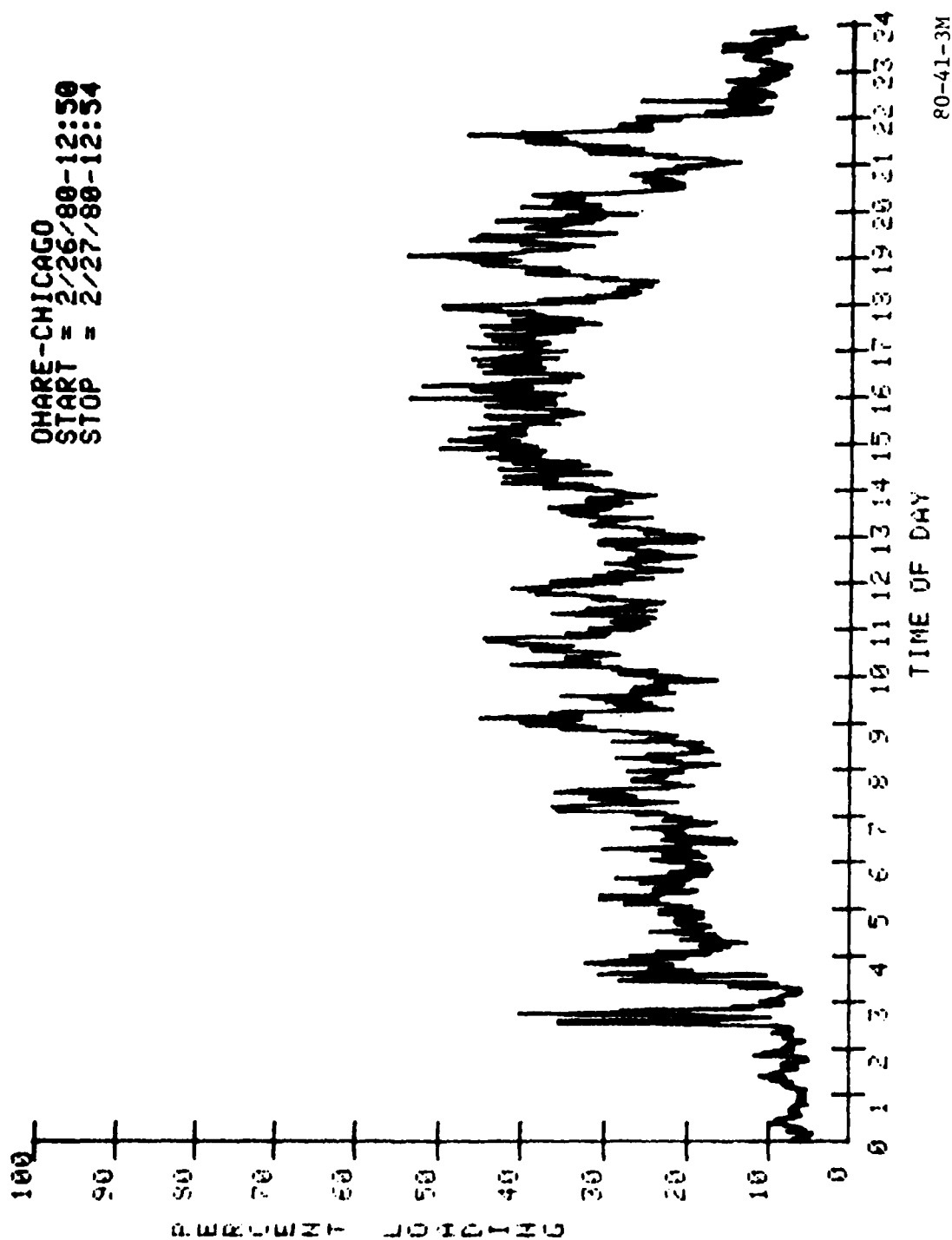


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 13 of 24)

OHARE-CHICAGO
START = 2/27/80-12:55
STOP = 2/28/80-12:56

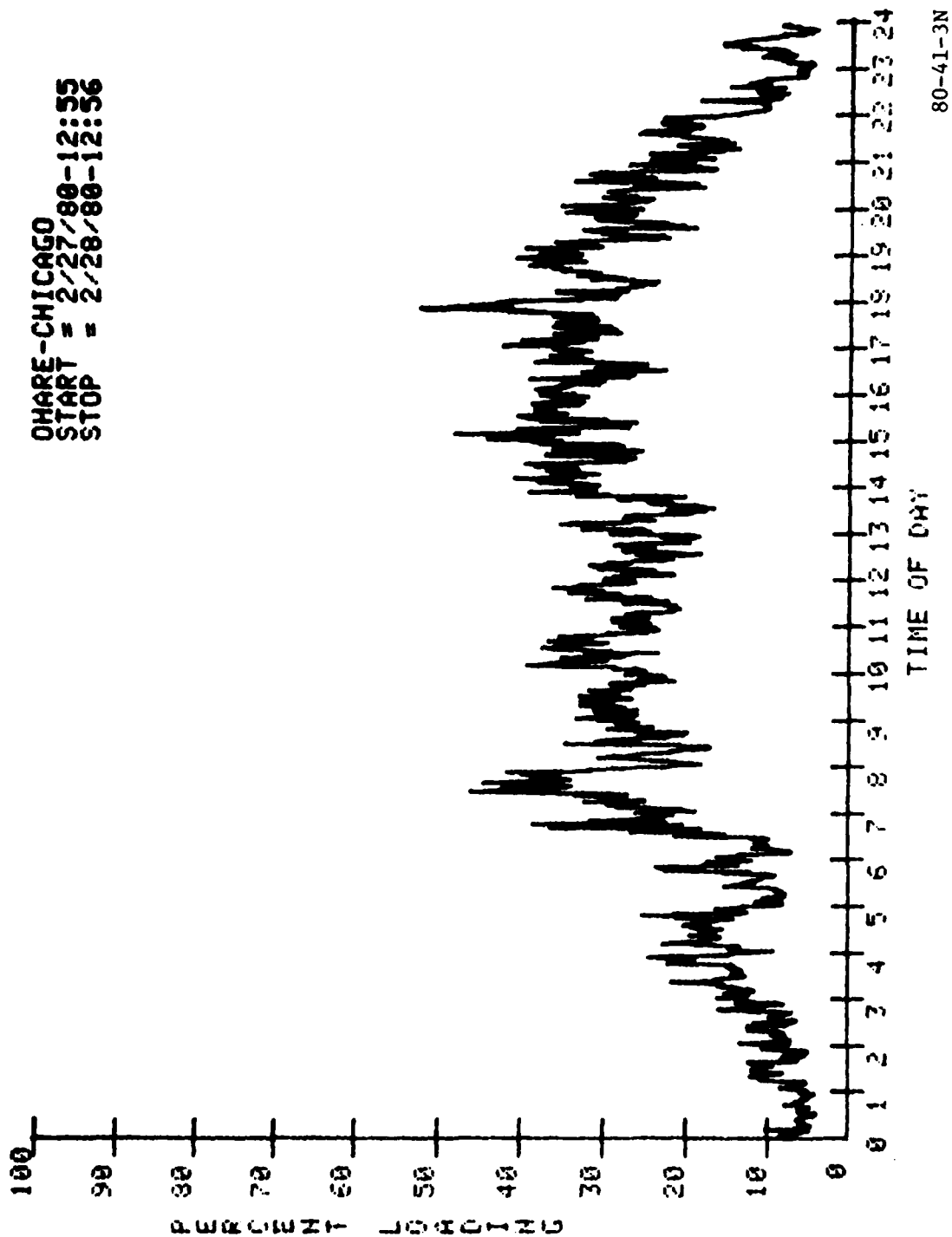


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 14 of 24)

OHARE-CHICAGO
START = 2/28/88-12:57
STOP = 2/29/88-12:58

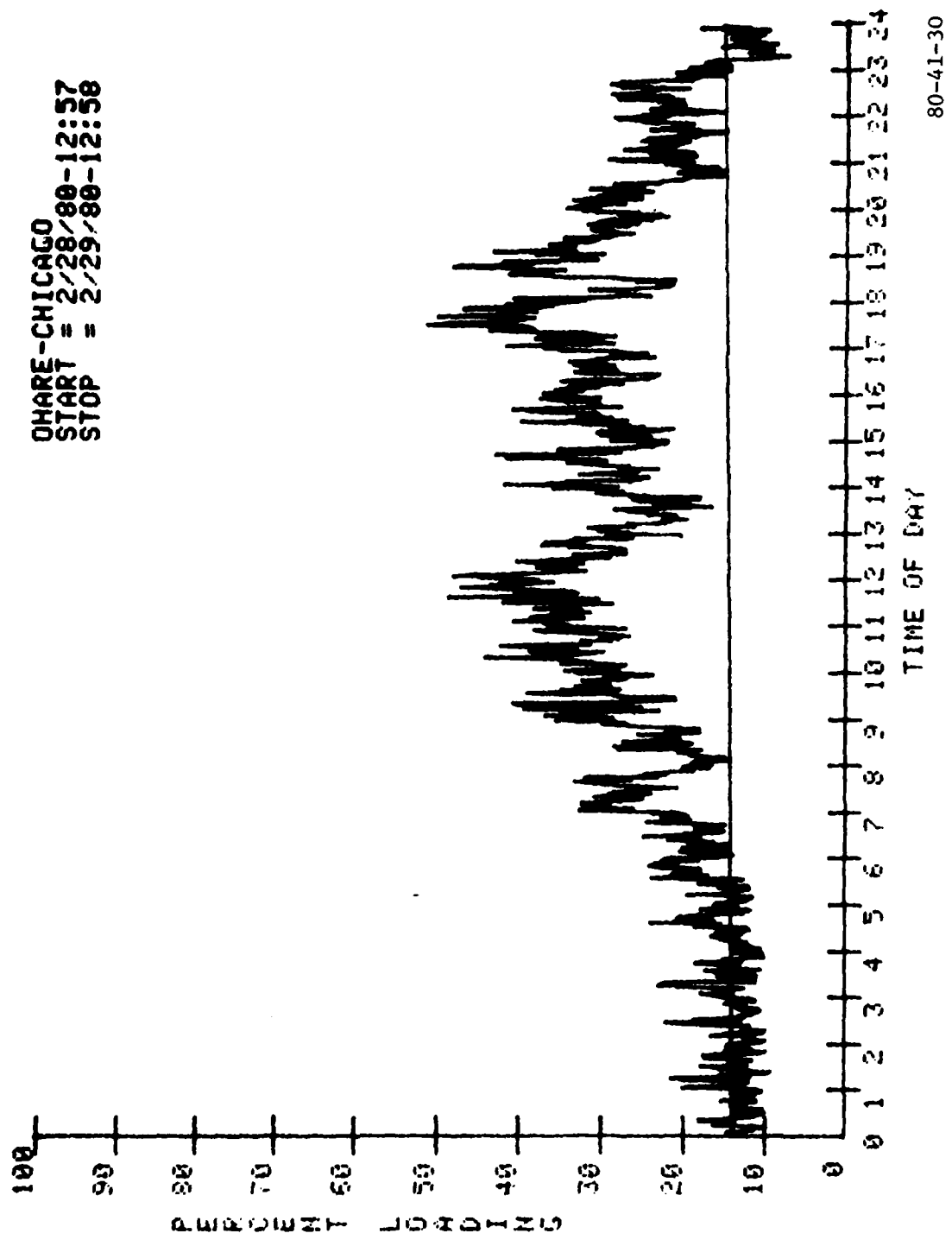


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 15 of 24)

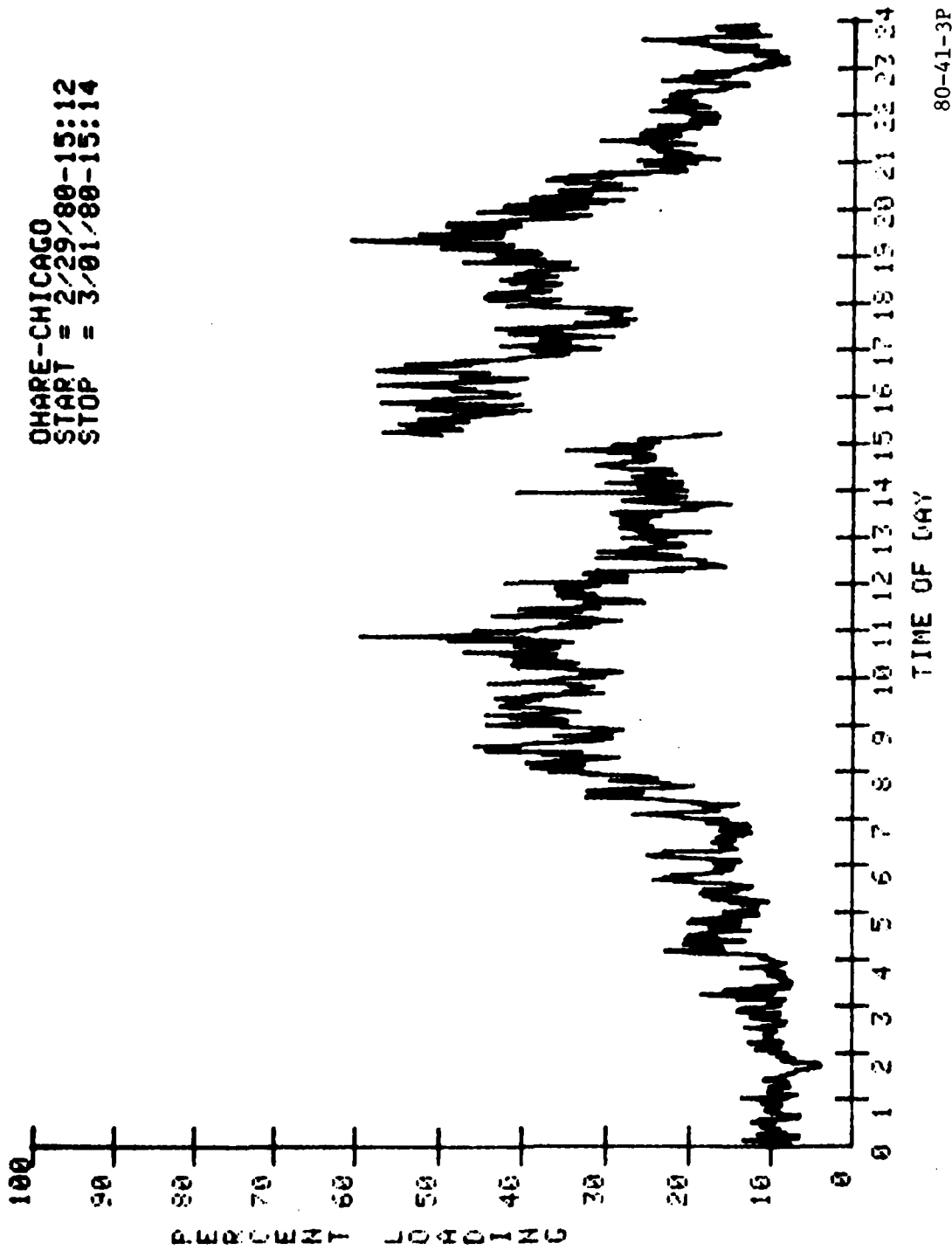


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 16 of 24)

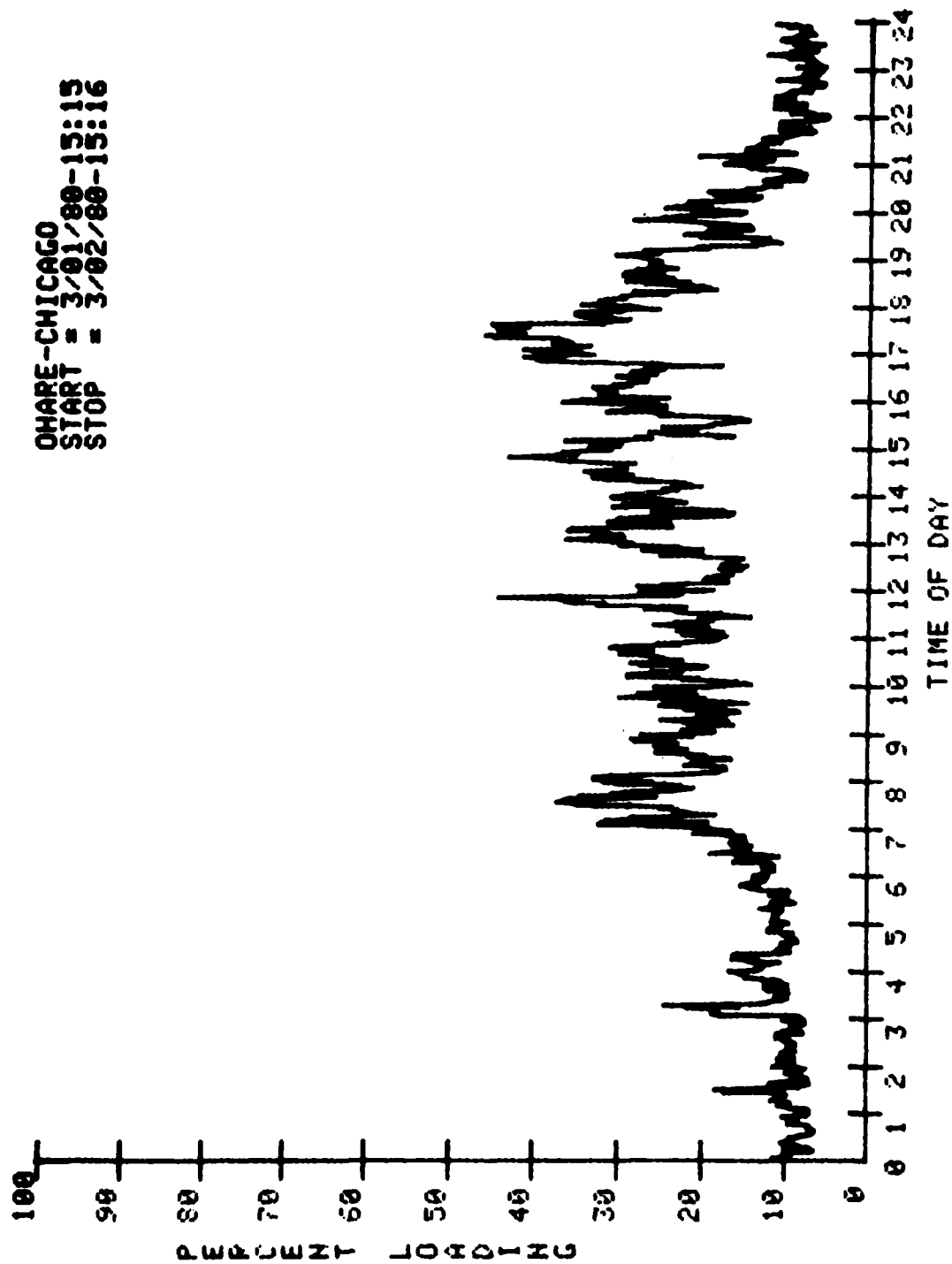
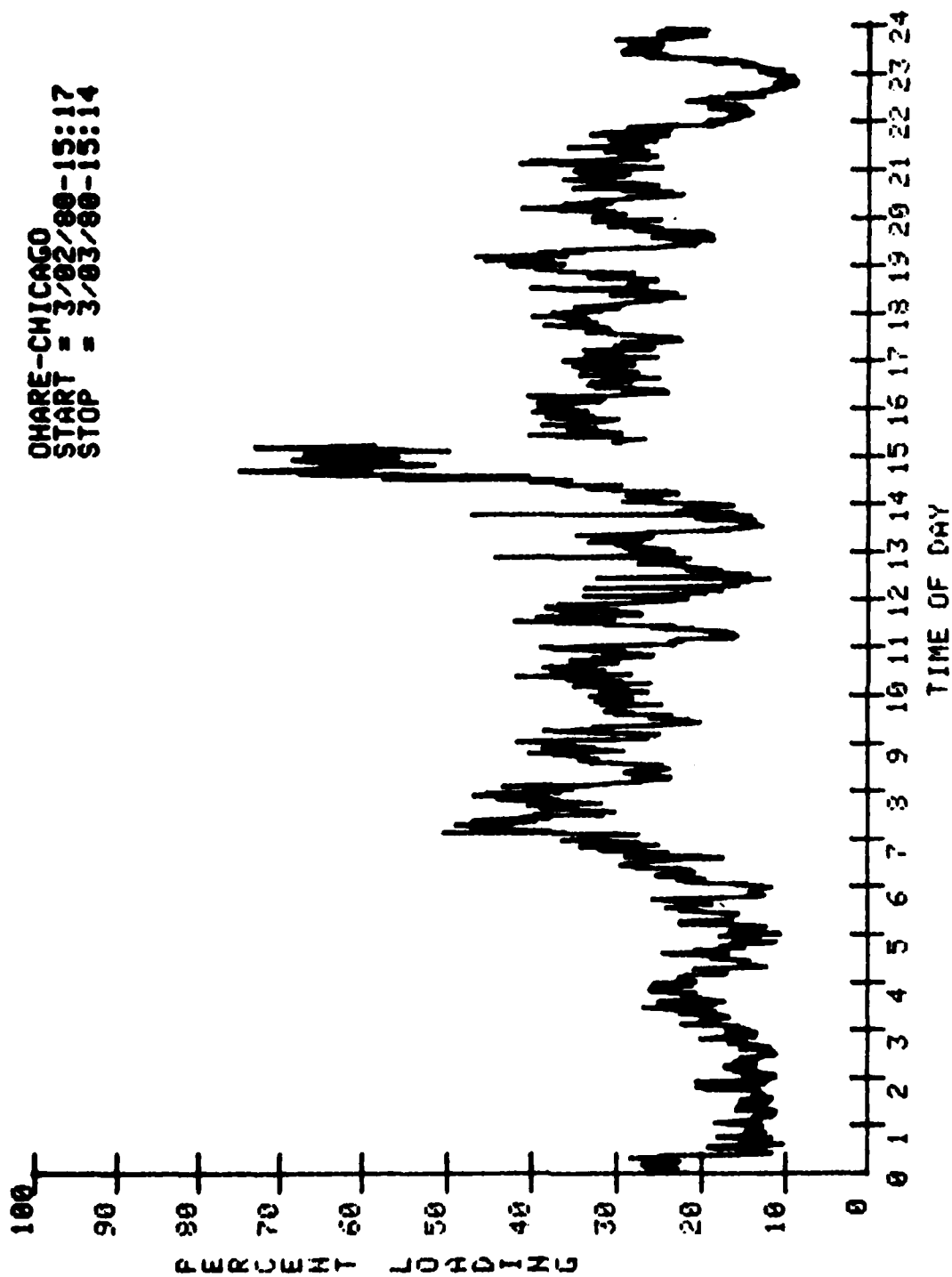


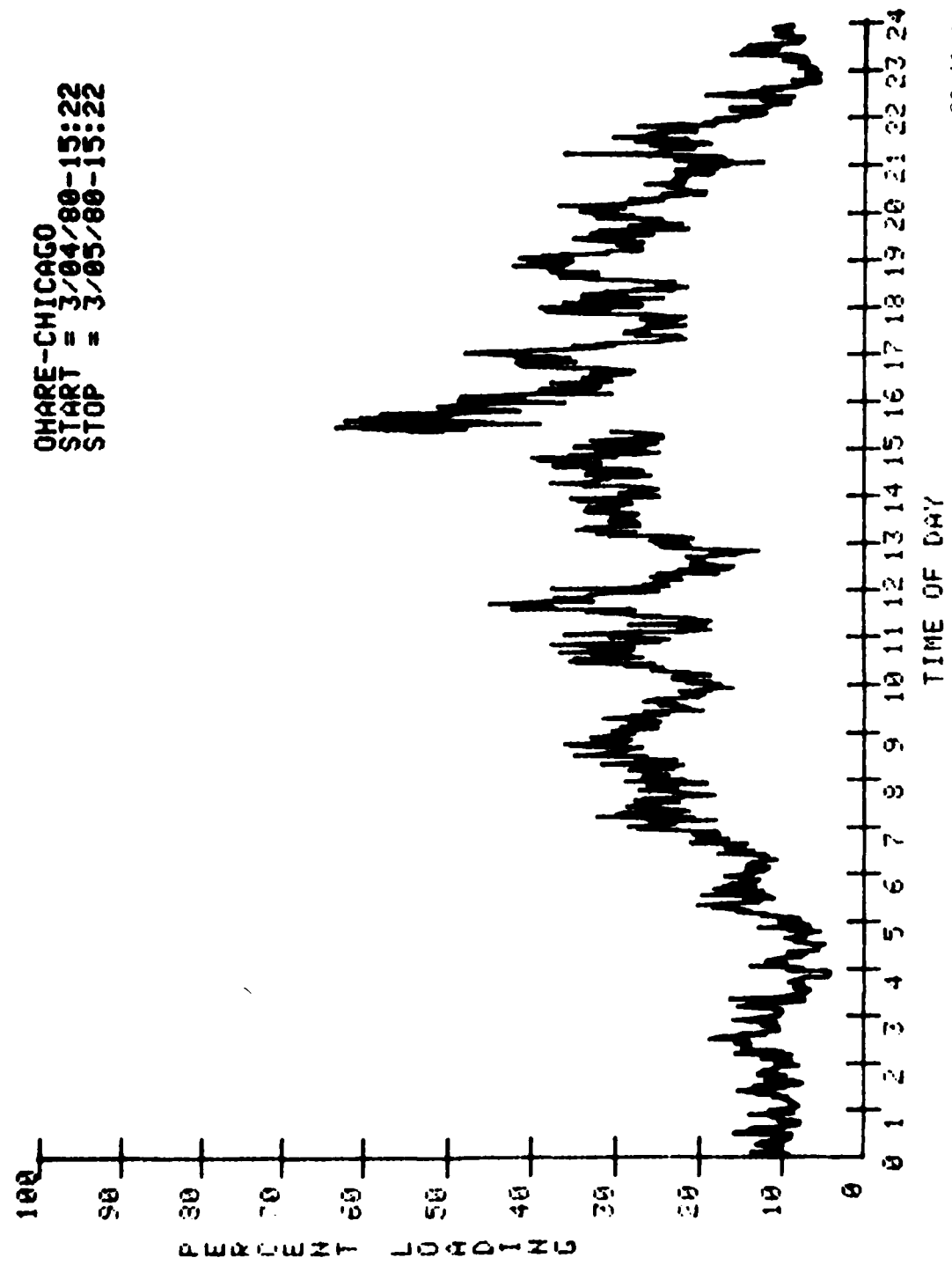
FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 17 of 24)



80-41-3R

FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 18 of 24)

OHARE-CHICAGO
START = 3/04/80-15:22
STOP = 3/05/80-15:22



80-41-3S

FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 19 of 24)

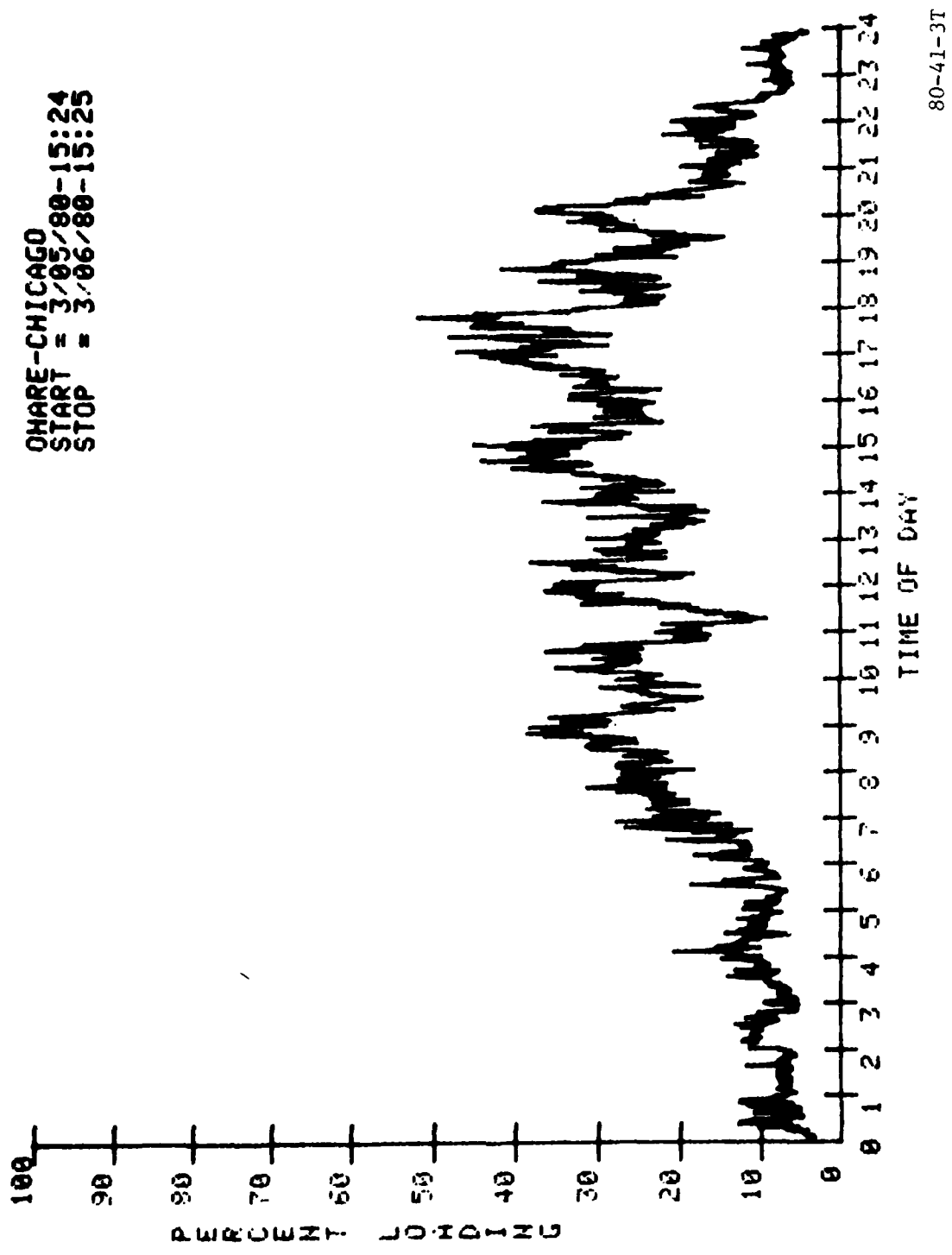
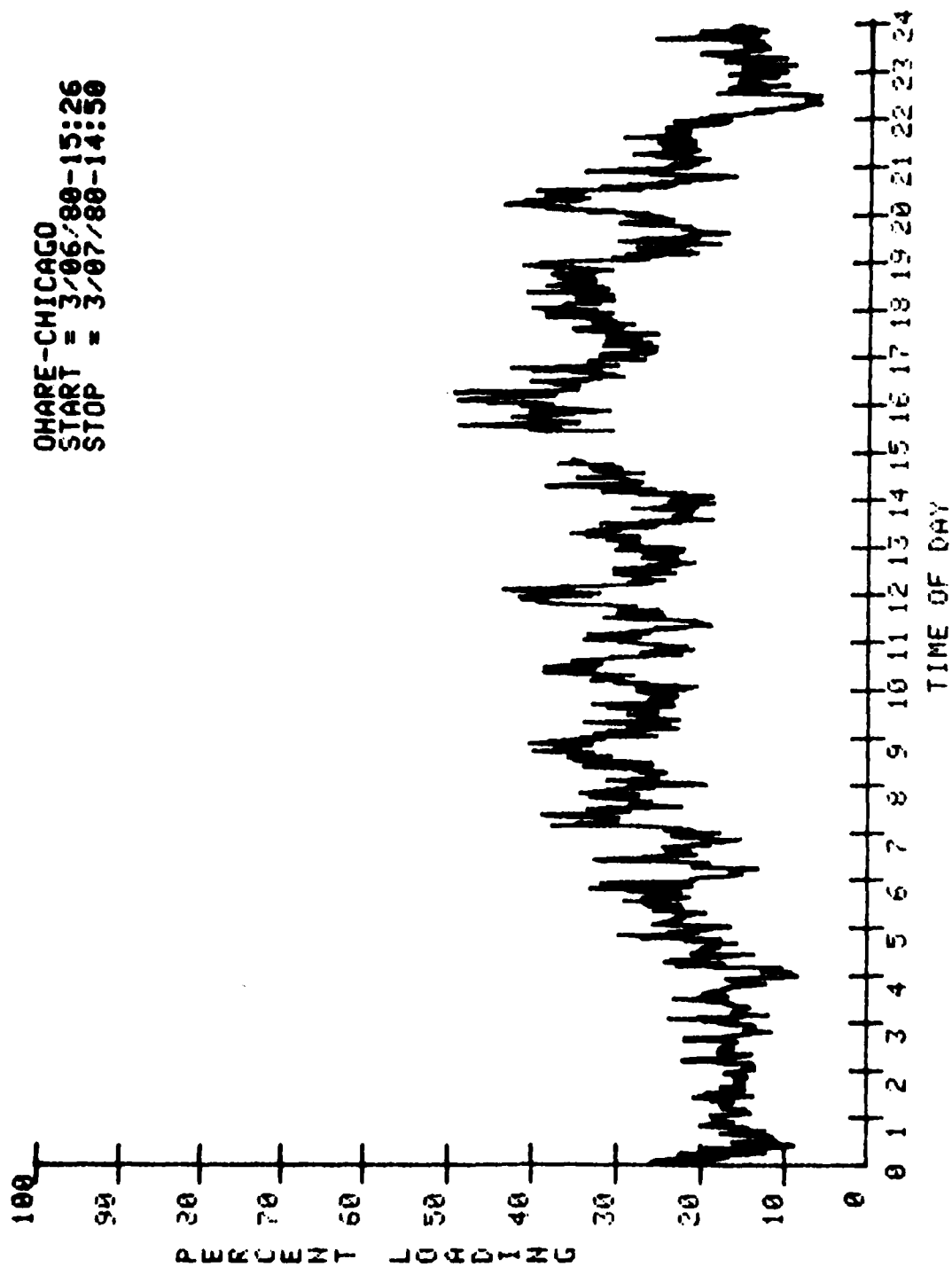


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 20 of 24)

OHARE-CHICAGO
 START = 3/06/80-15:26
 STOP = 3/07/80-14:50



80-41-3U

FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 21 of 24)

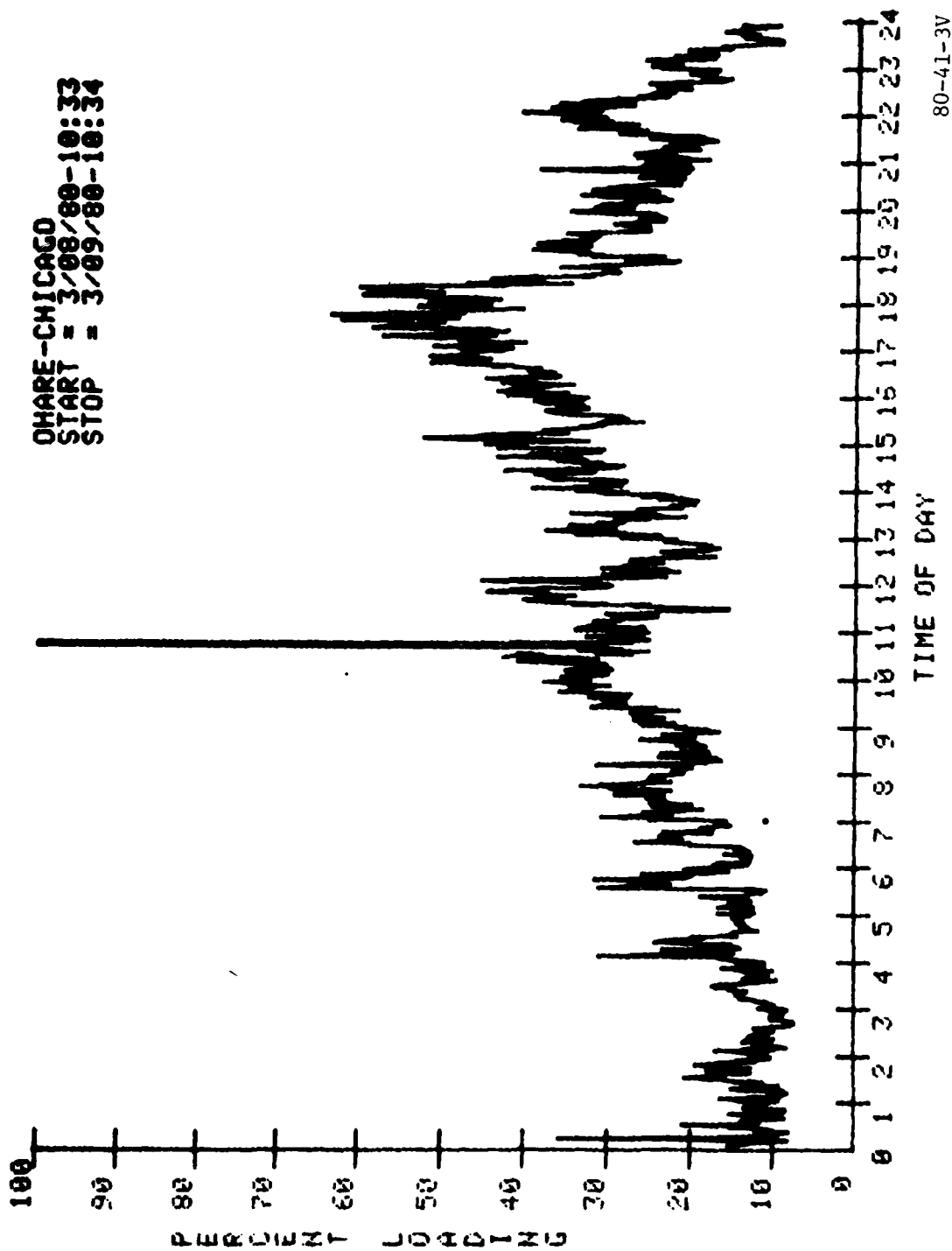


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 22 of 24)

OHARE-CHICAGO
 START = 3/09/80-10:35
 STOP = 3/10/80-10:37

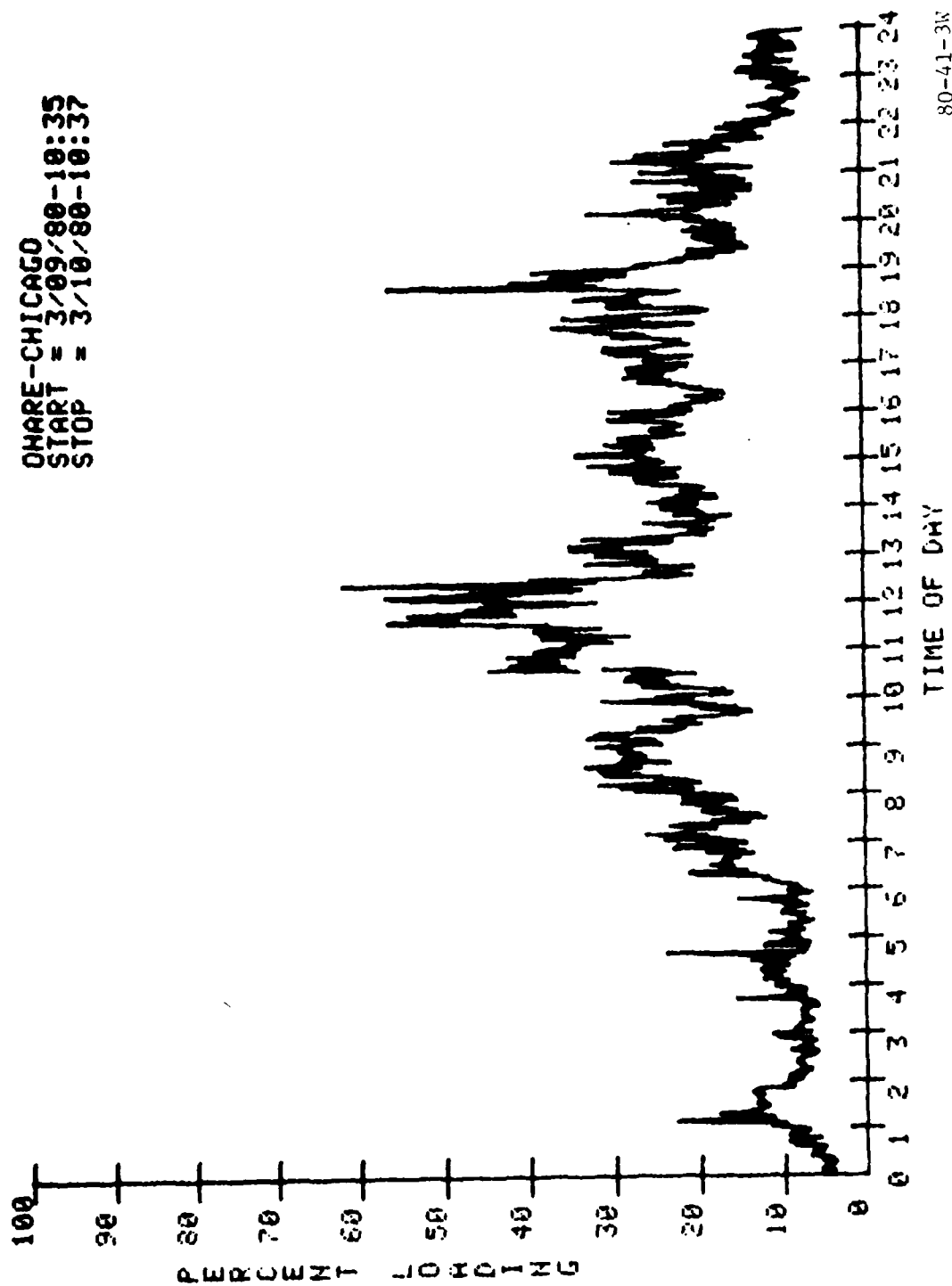


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 23 of 24)

80-41-3W

OHARE-CHICAGO
START = 3/10/80-10:38
STOP = 3/11/80-07:39

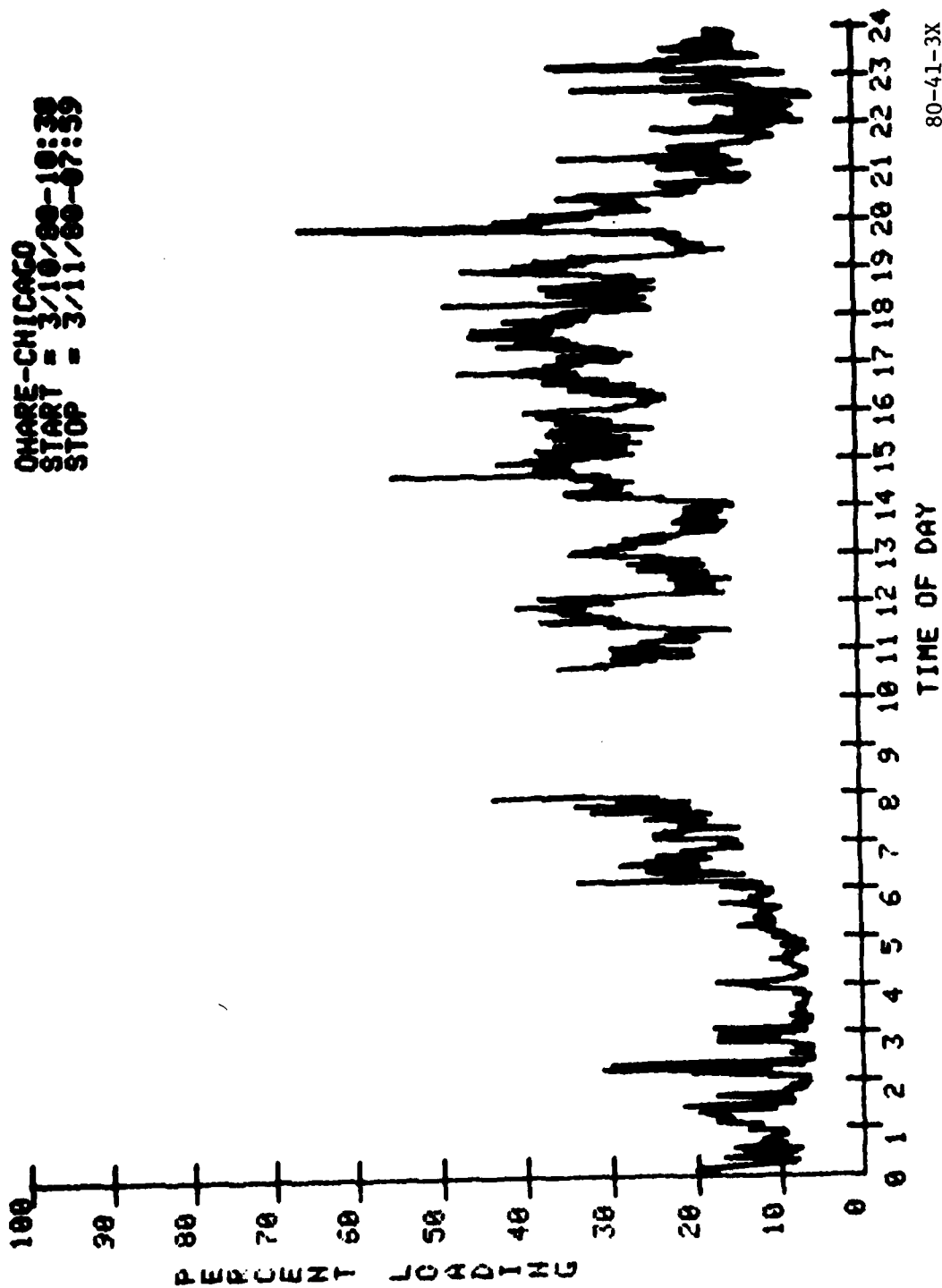


FIGURE 3. MEASURED INTERROGATION RATE CHICAGO, ILLINOIS (Sheet 24 of 24)

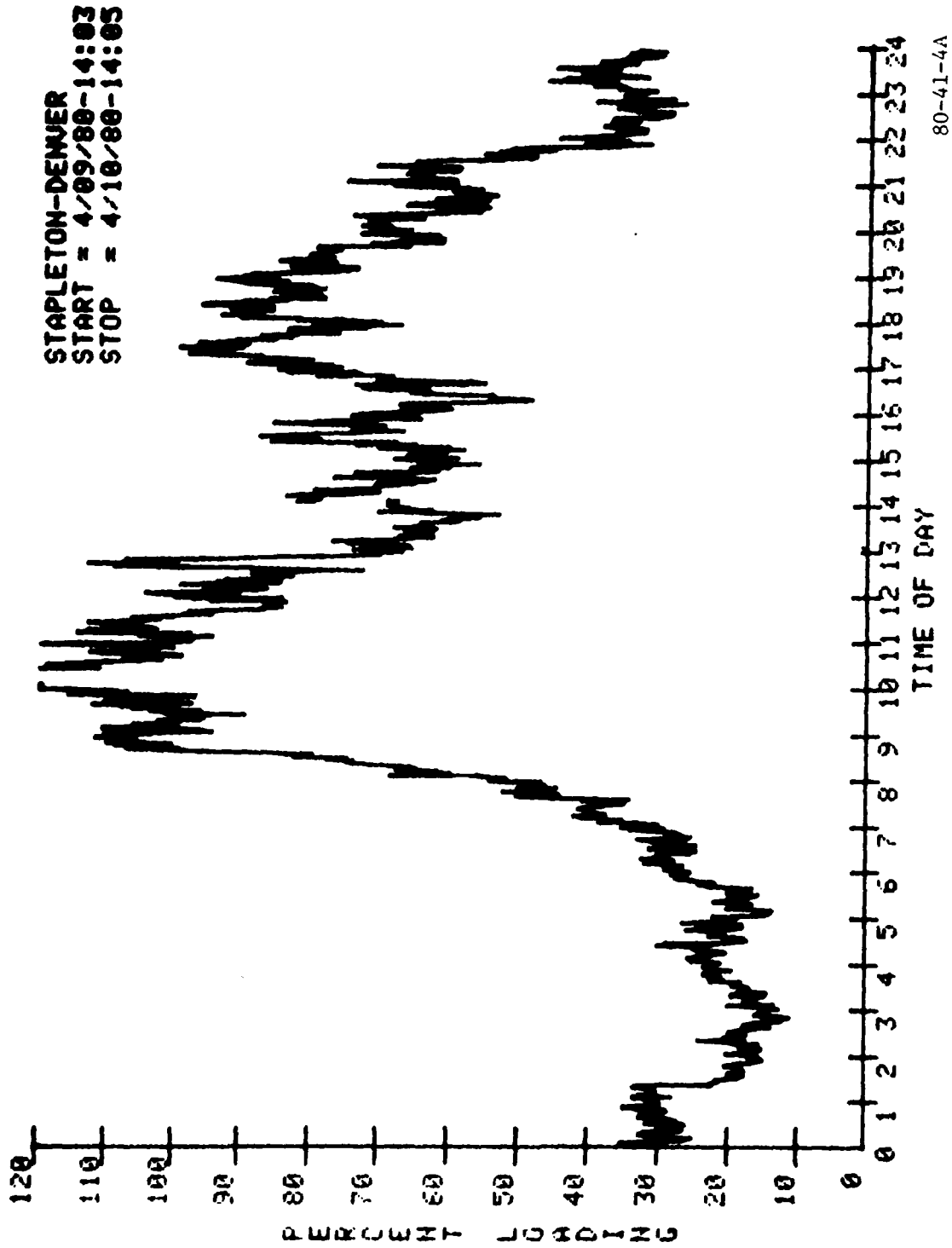


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 1 of 30)

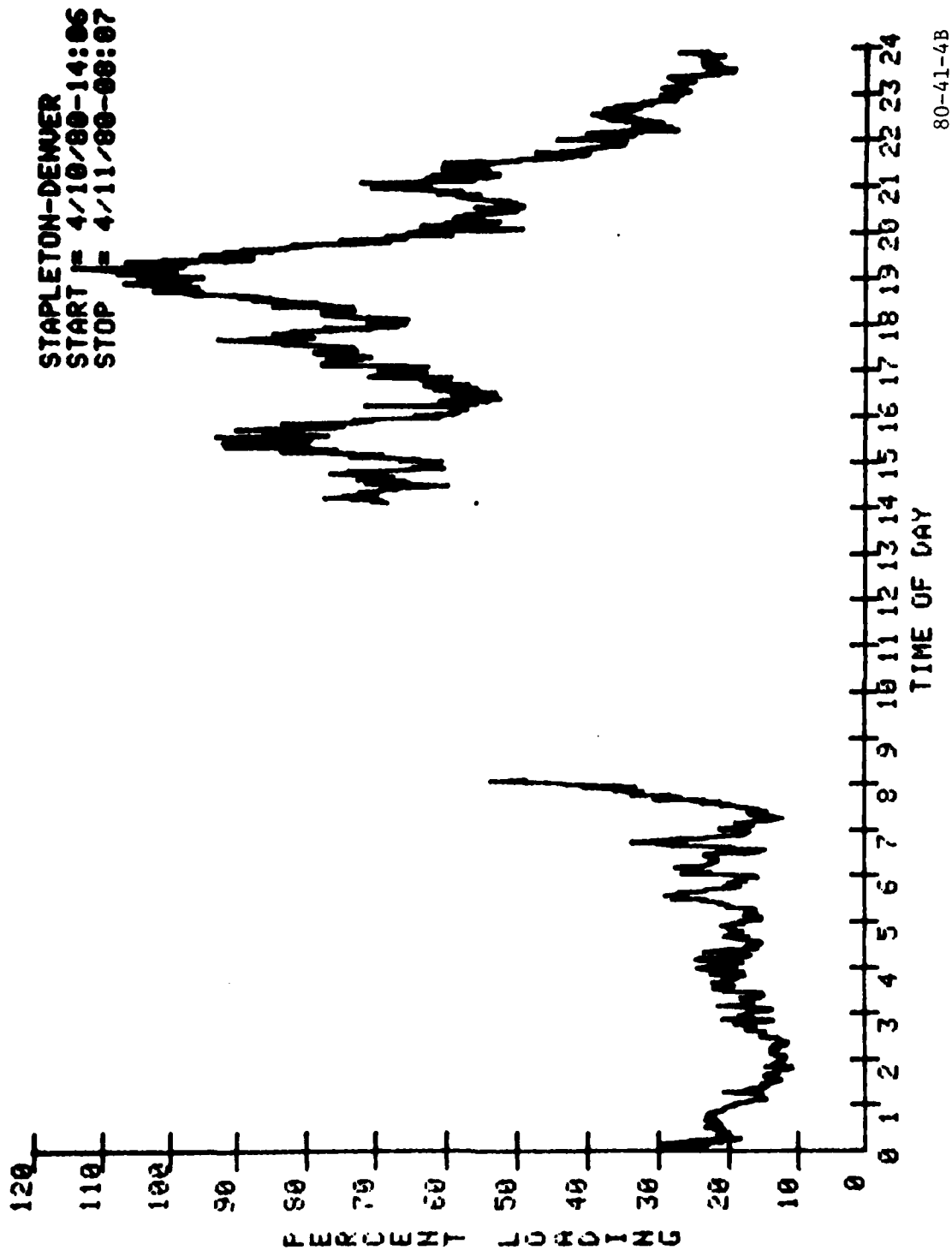


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 2 of 30)

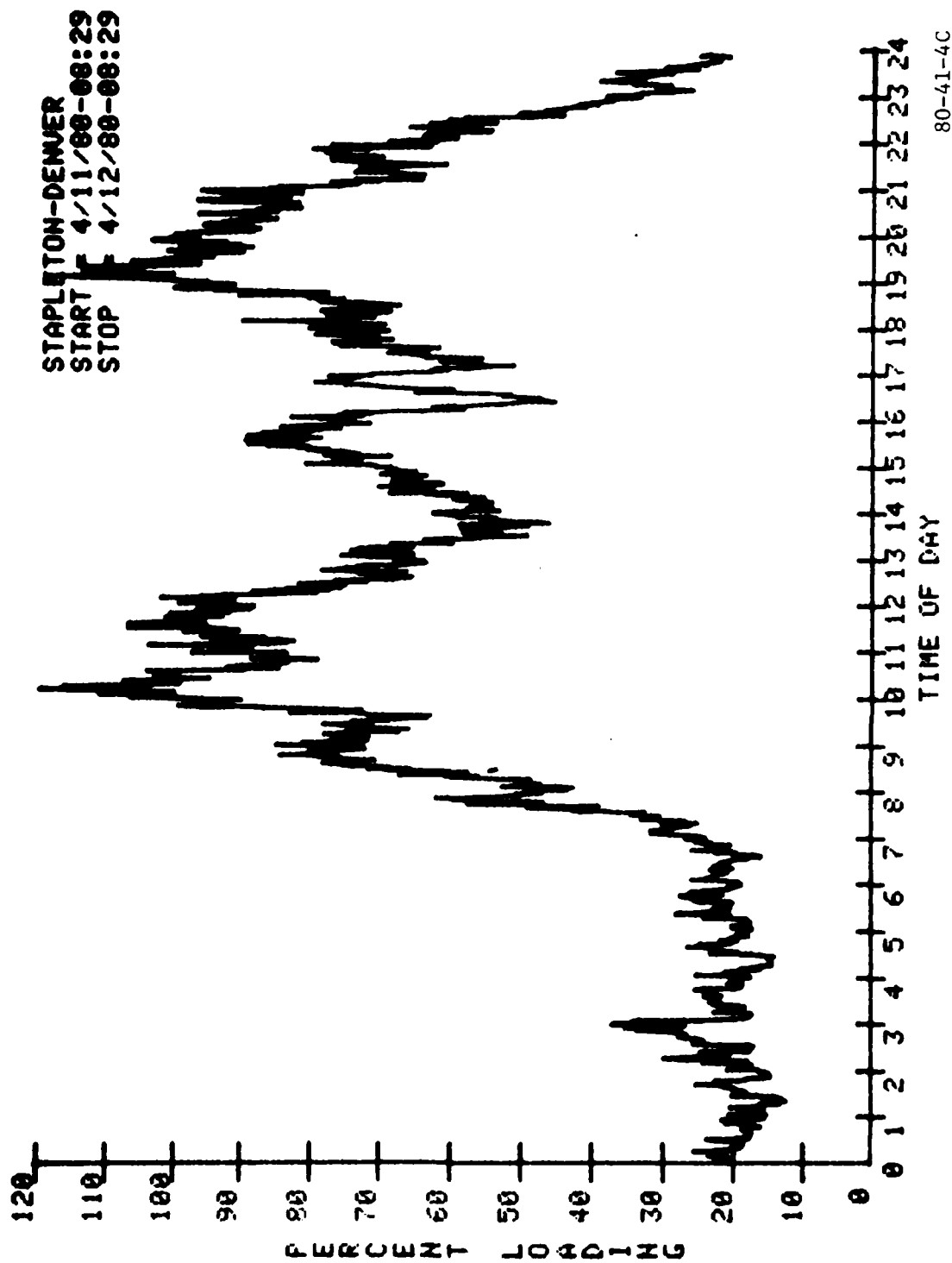


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 3 of 30)

STAPLETON-DENVER
 START = 4/12/80-08:30
 STOP = 4/13/80-08:30

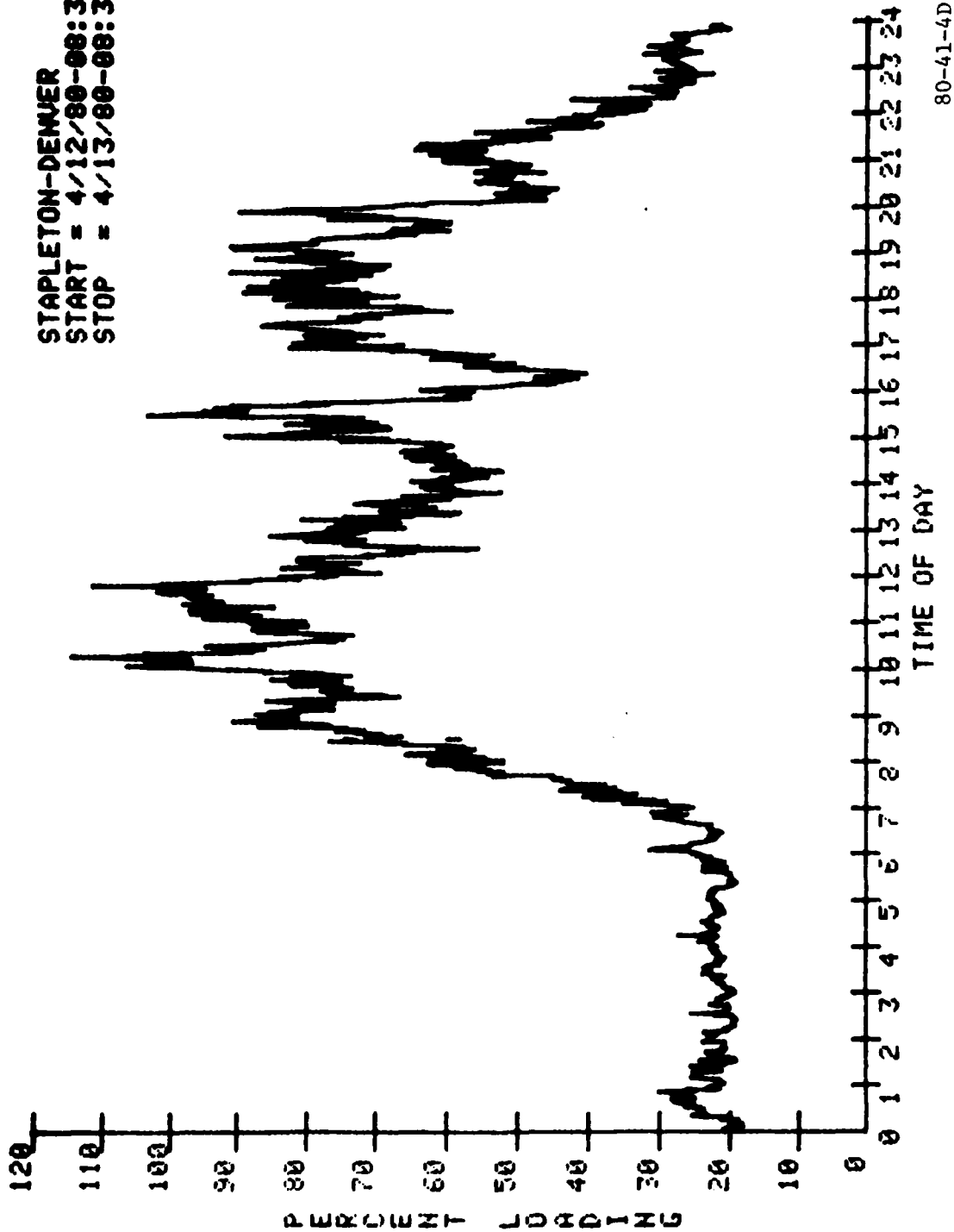


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 4 of 30)

80-41-4D

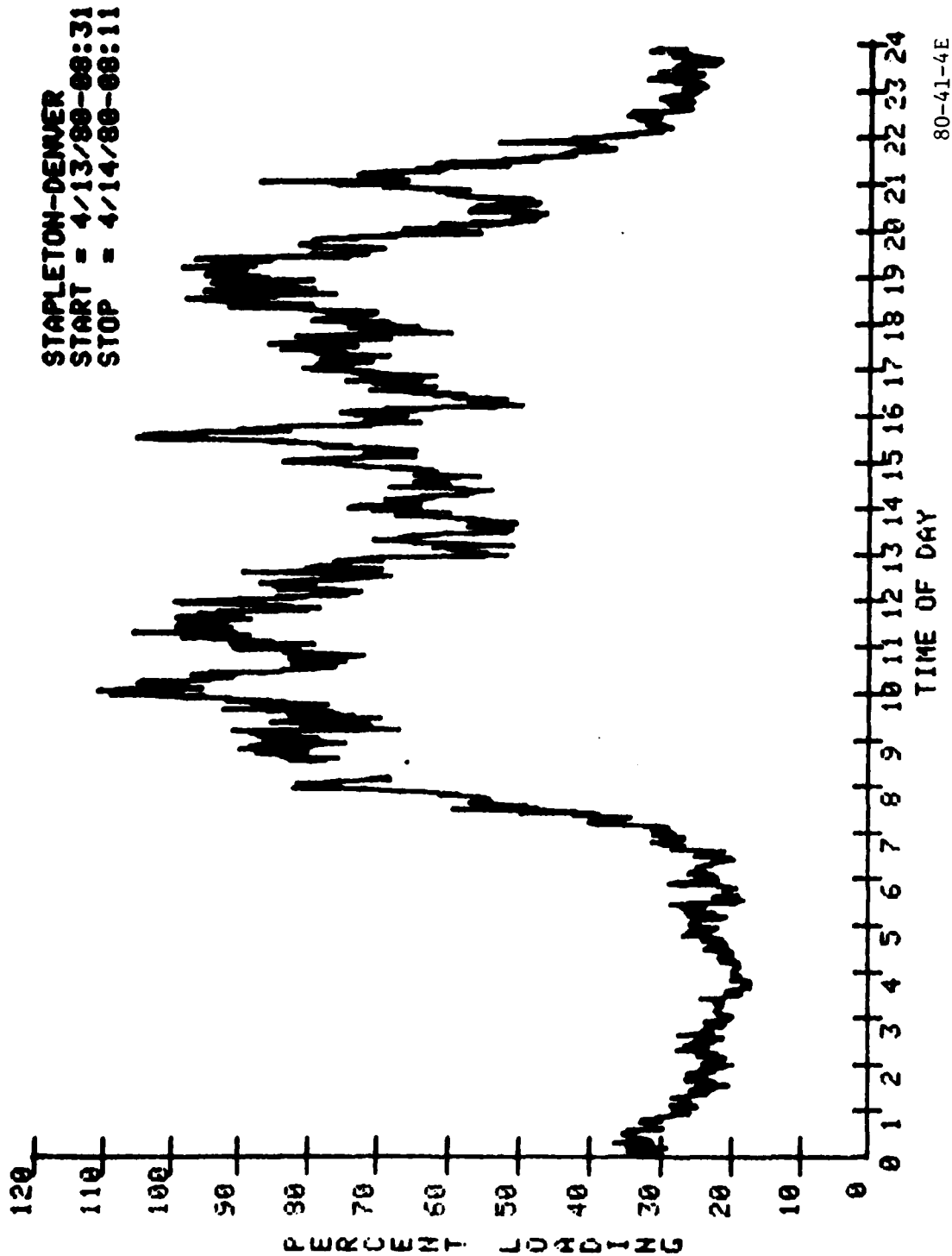


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 5 of 30)

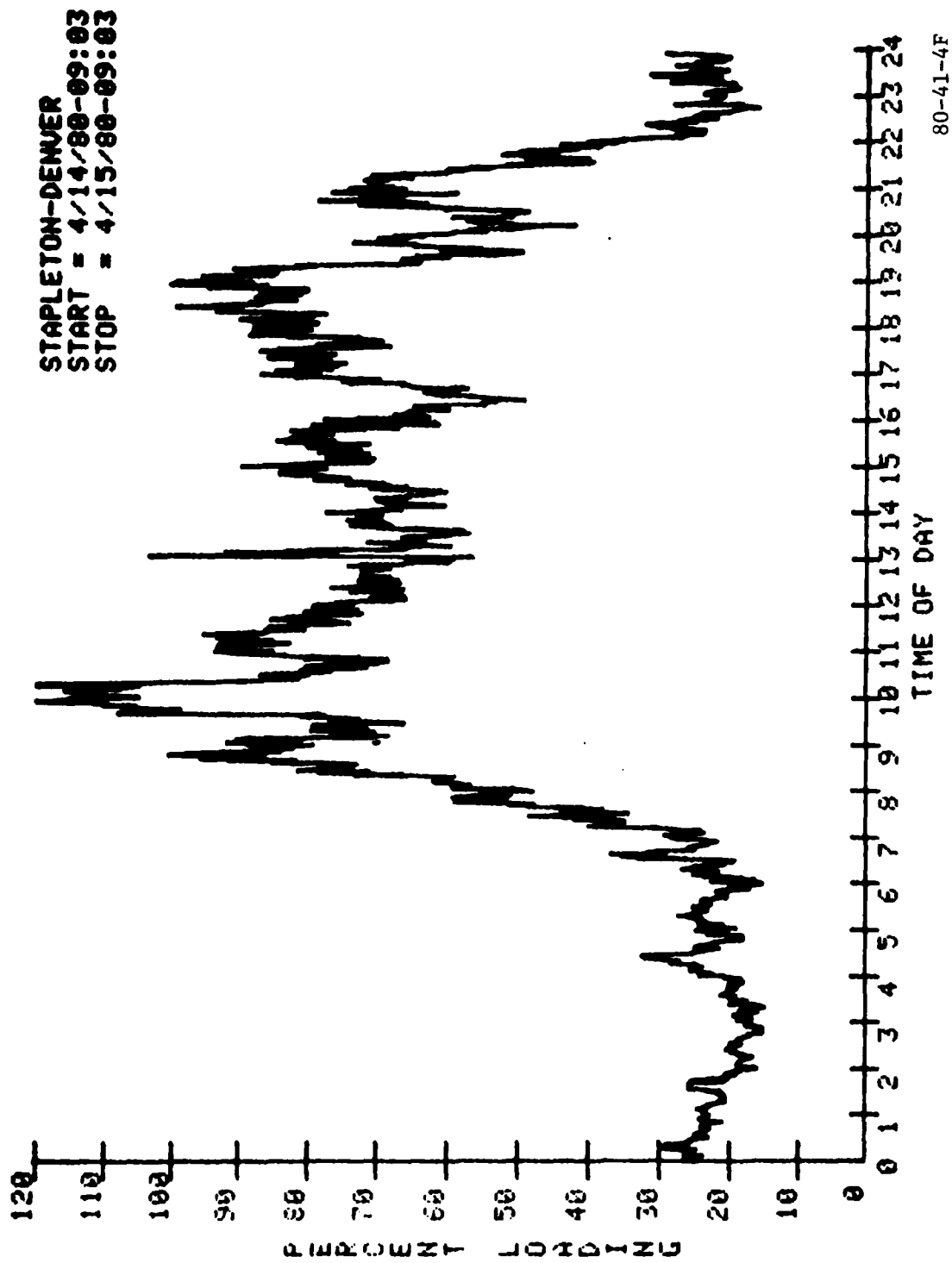


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 6 of 30)

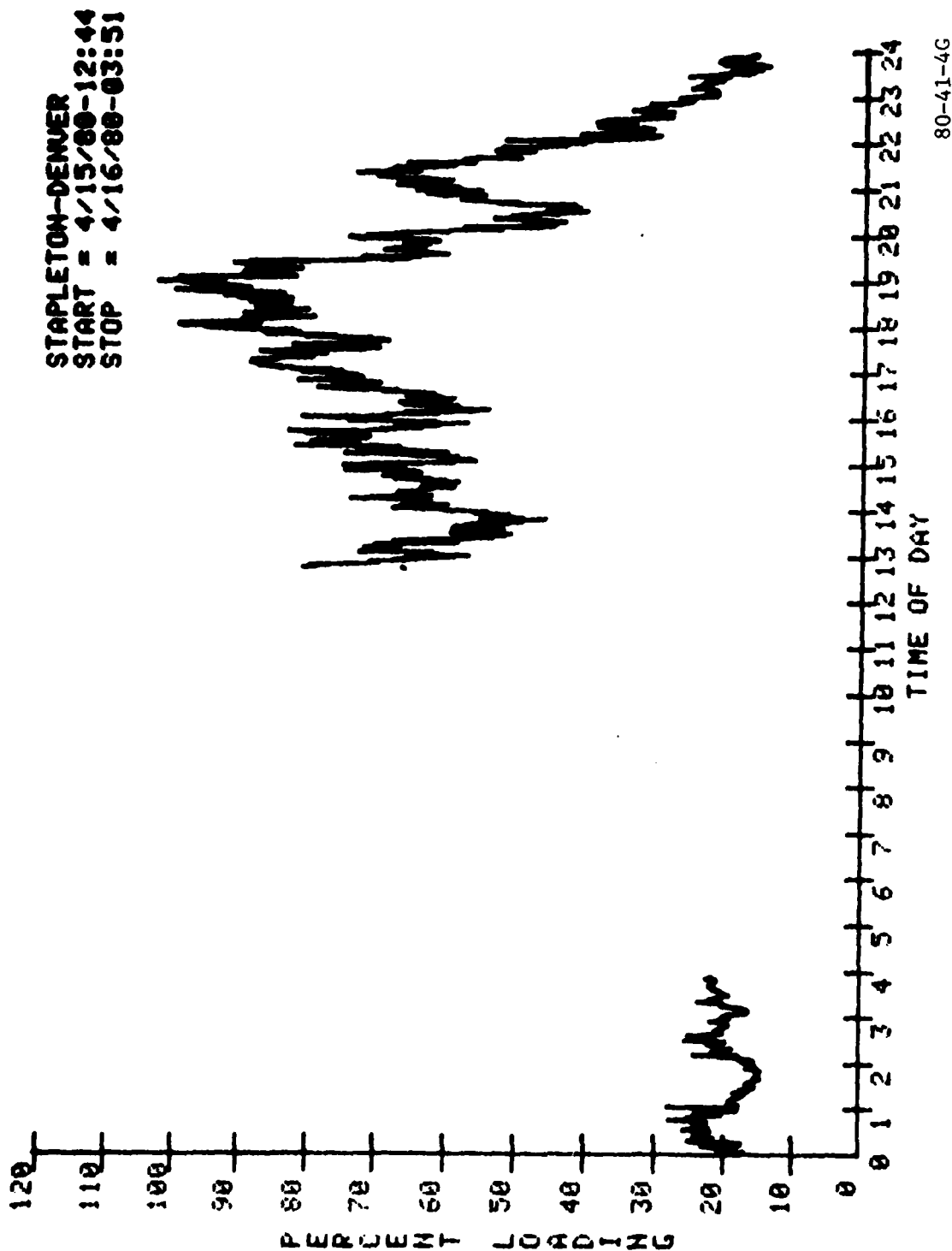


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 7 of 30)

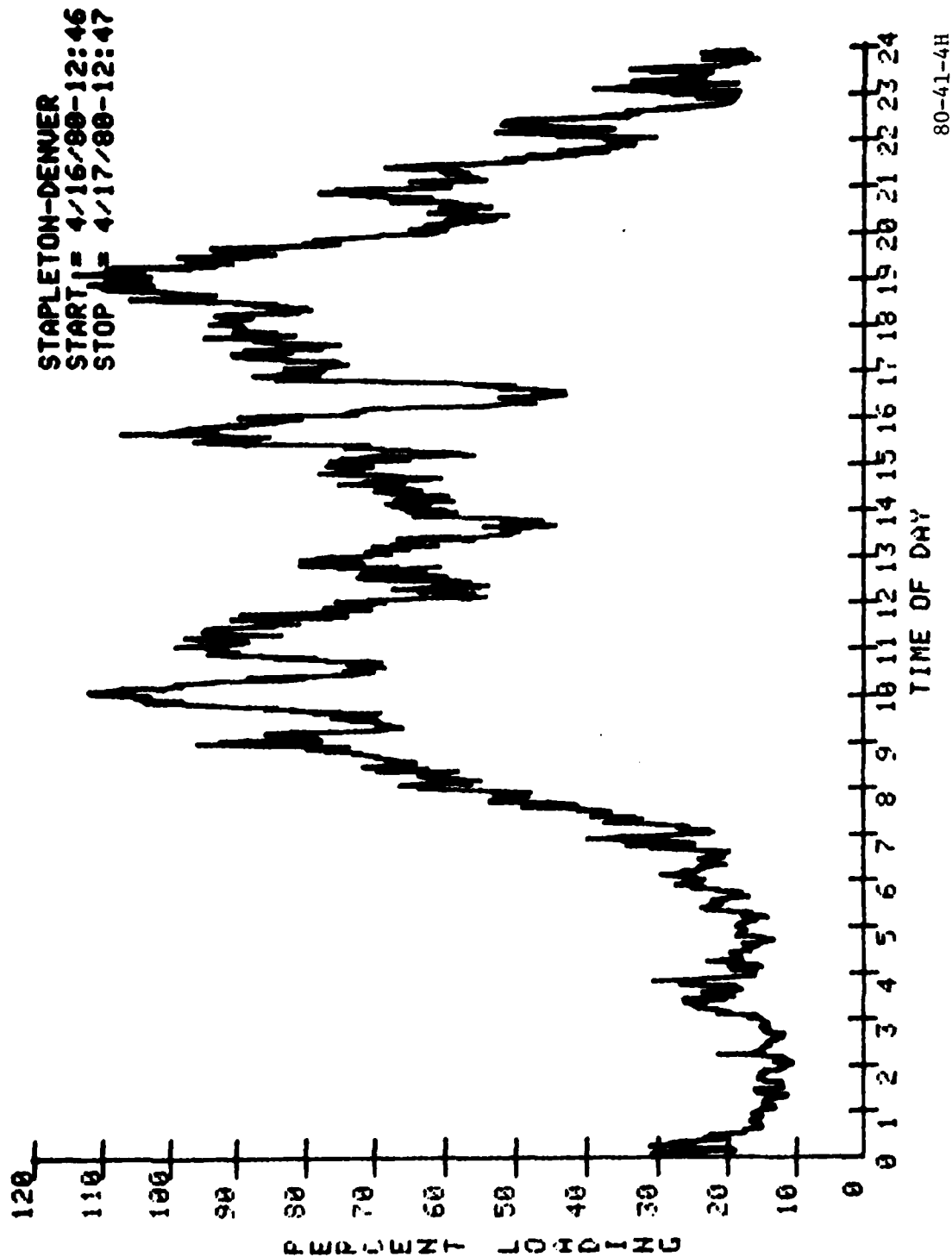


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 8 of 30)

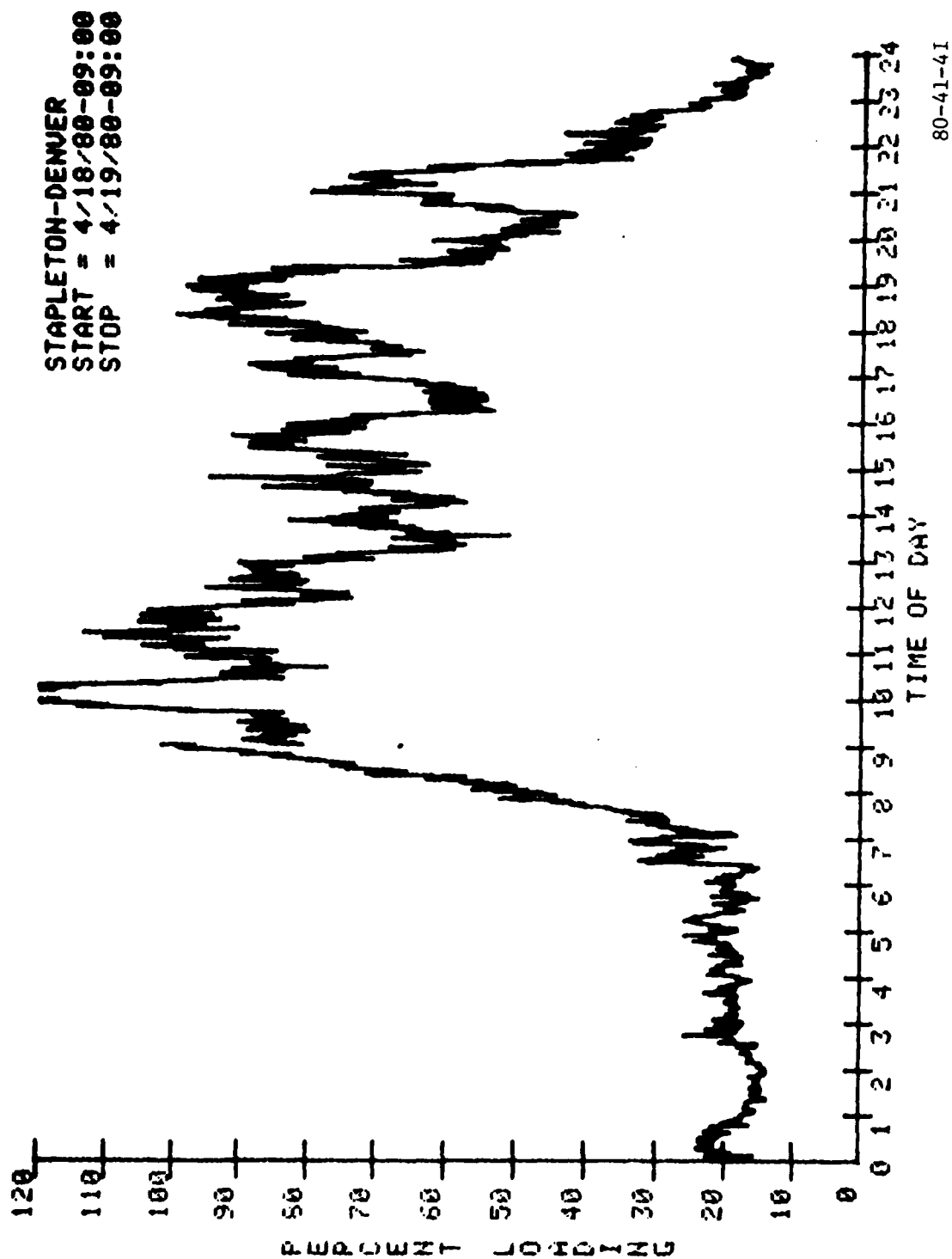
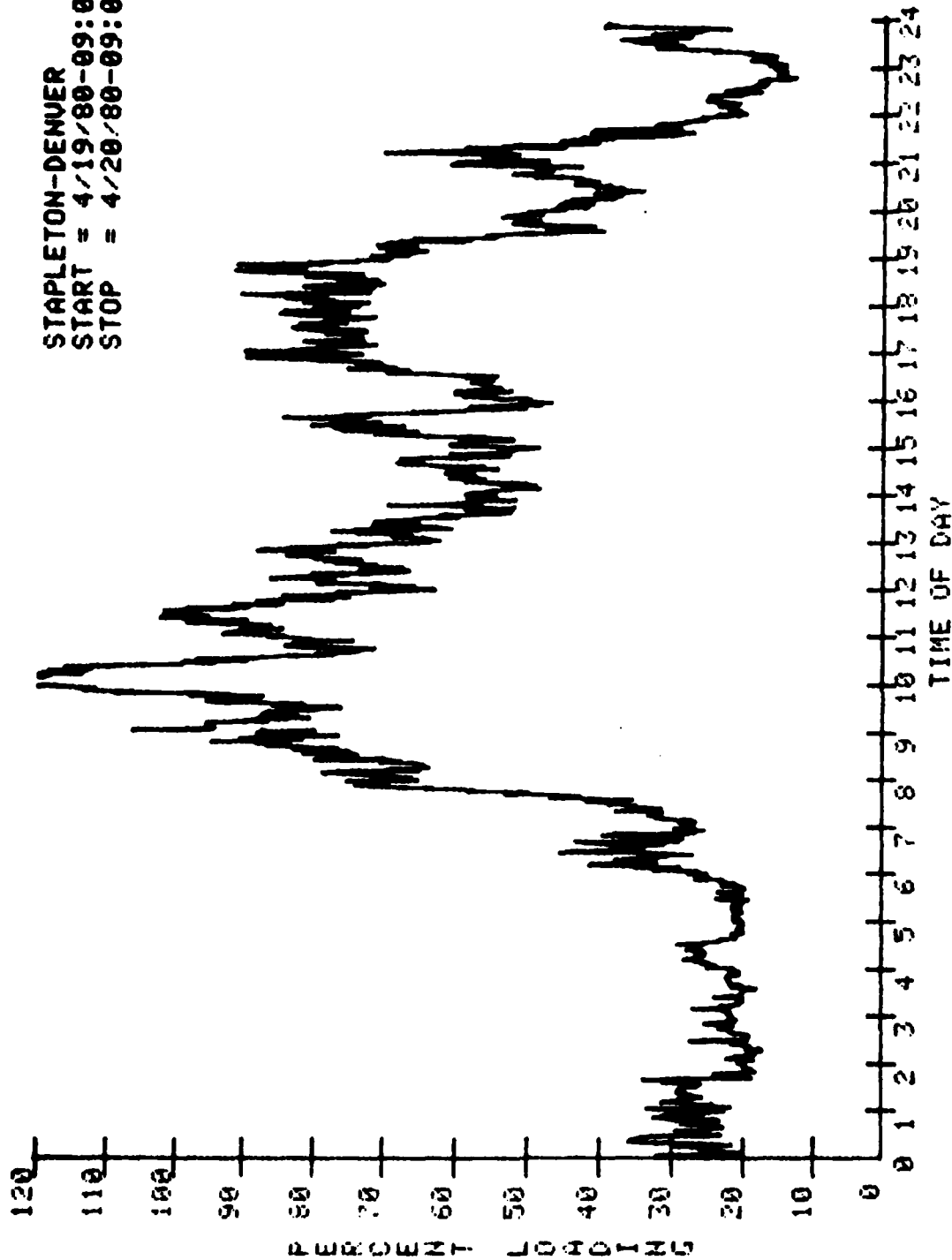


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 9 of 30)

STAPLETON-DENVER
 START = 4/19/80-09:01
 STOP = 4/20/80-09:02



80-41-4J

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 10 of 30)

STAPLETON-DENVER
 START = 4/20/88-09:03
 STOP = 4/21/88-08:01

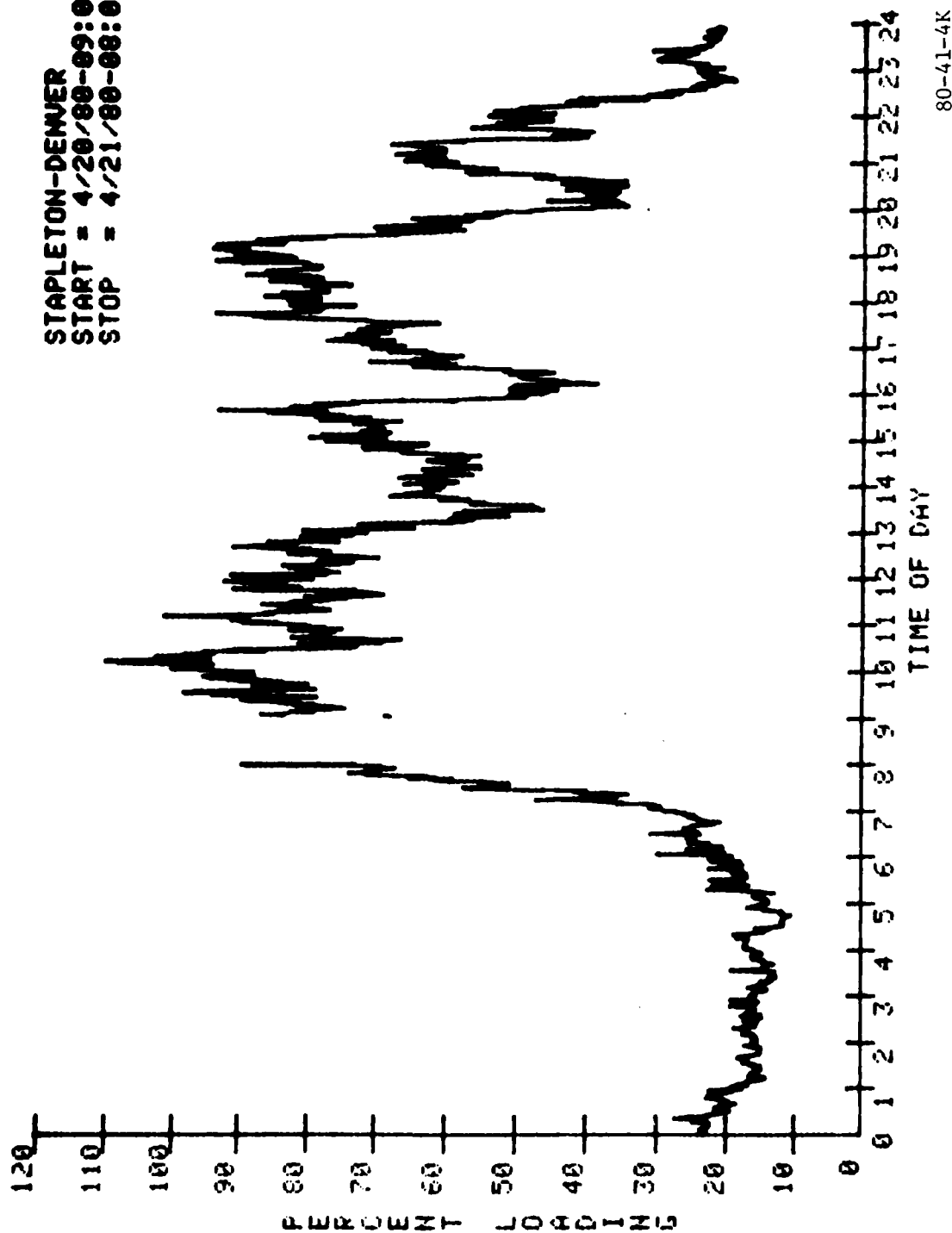


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 11 of 30)

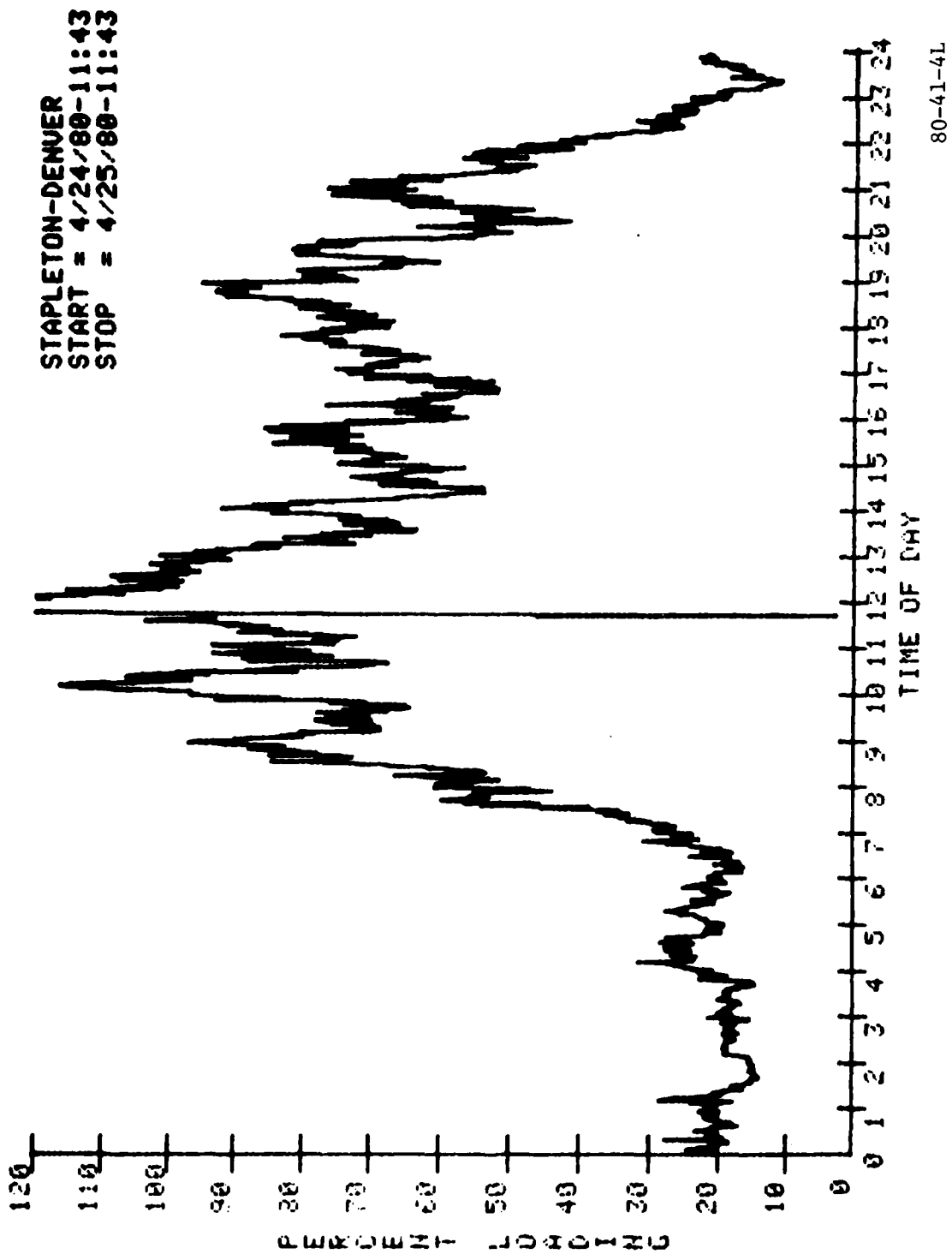


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 12 of 30)

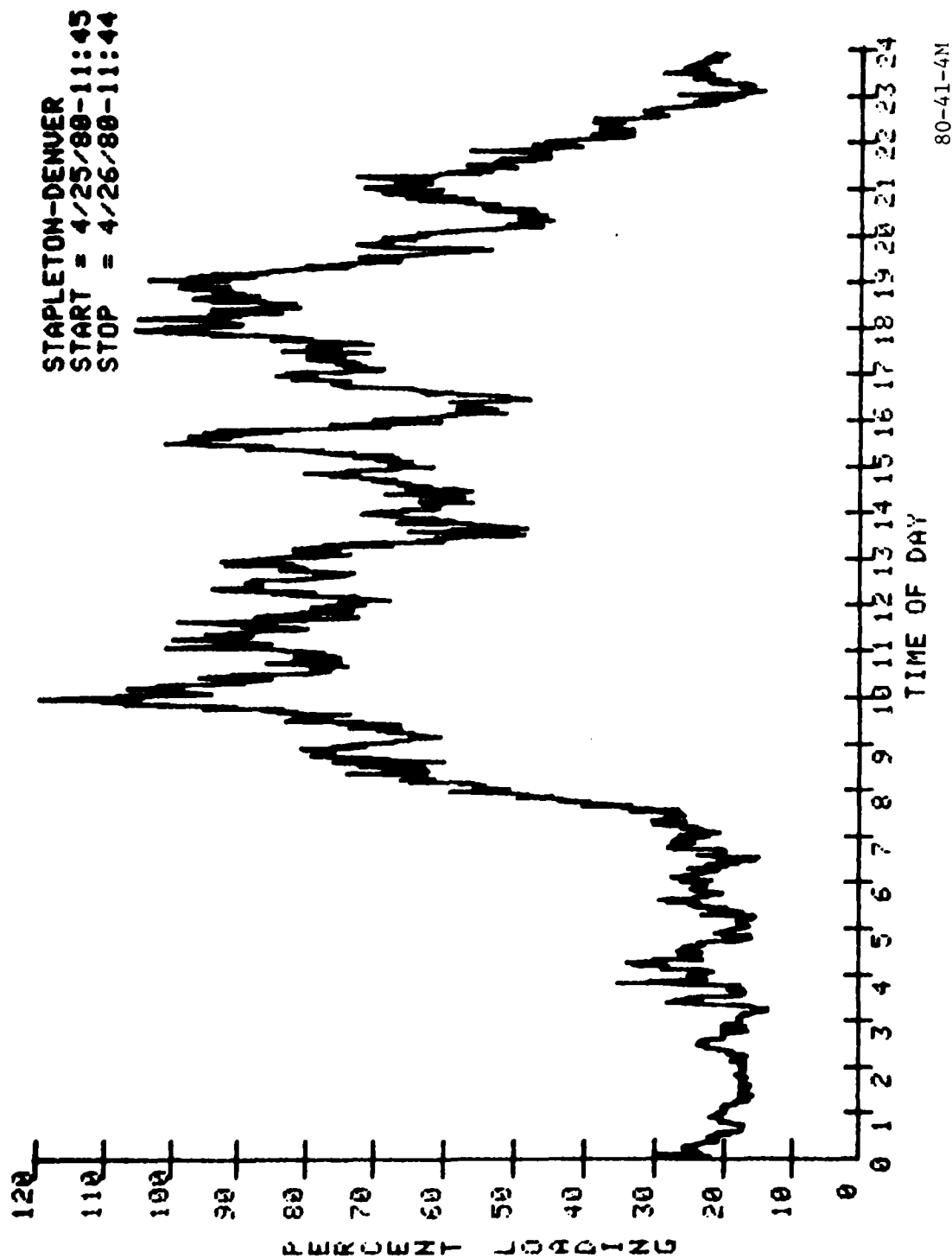


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 13 of 30)

STAPLETON-DENVER
 START = 4/26/80-11:45
 STOP = 4/27/80-11:46

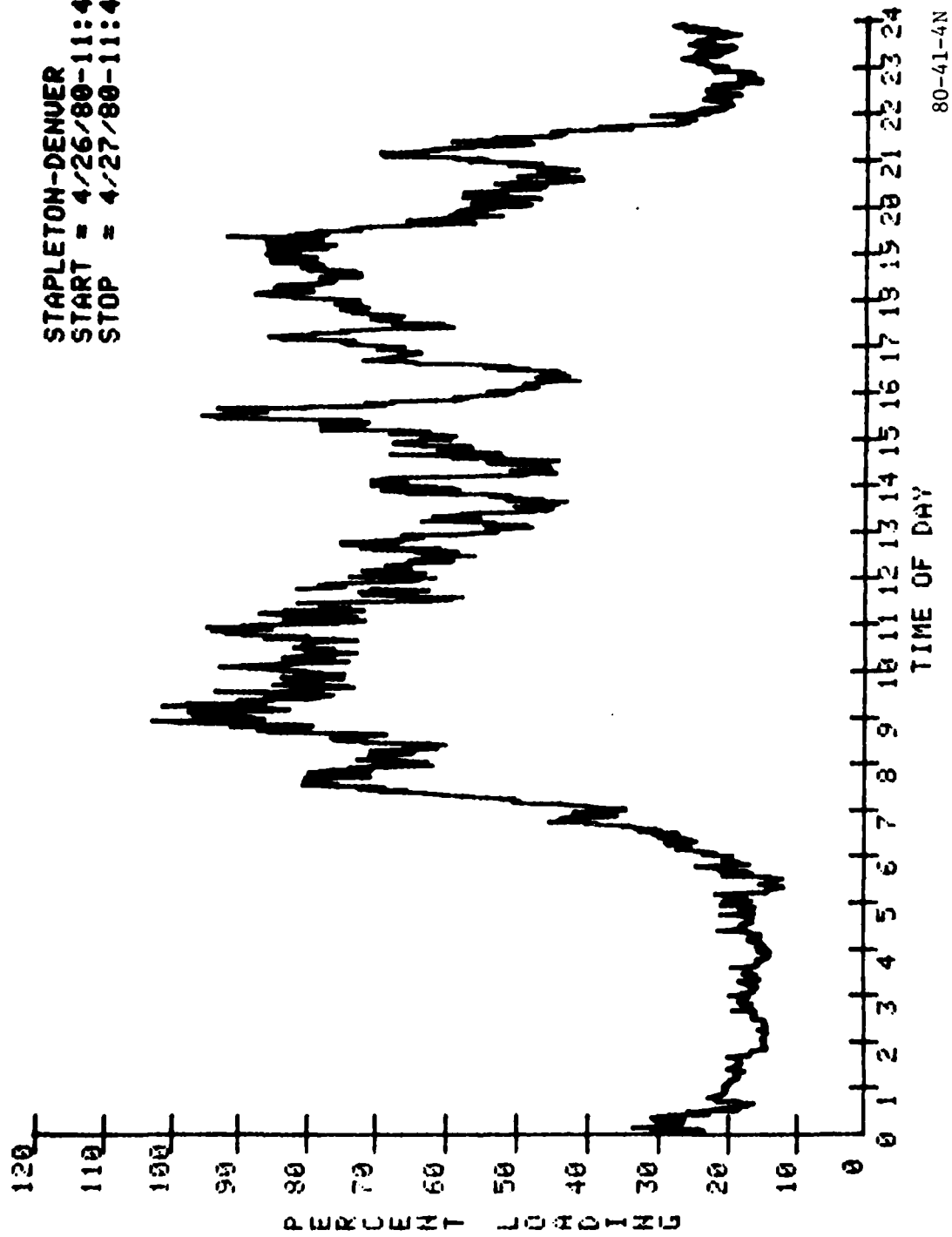


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 14 of 30)

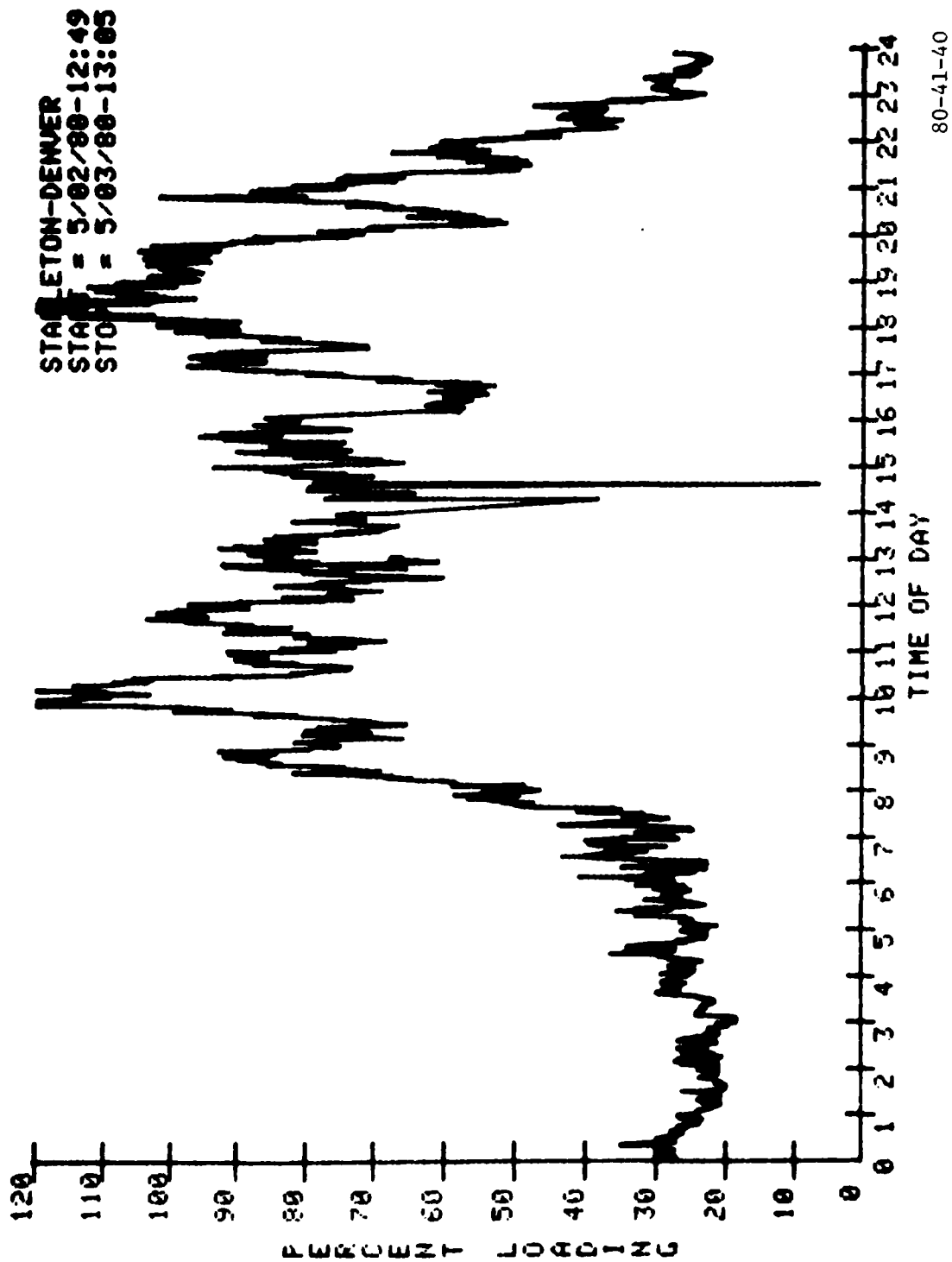


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 15 of 30)

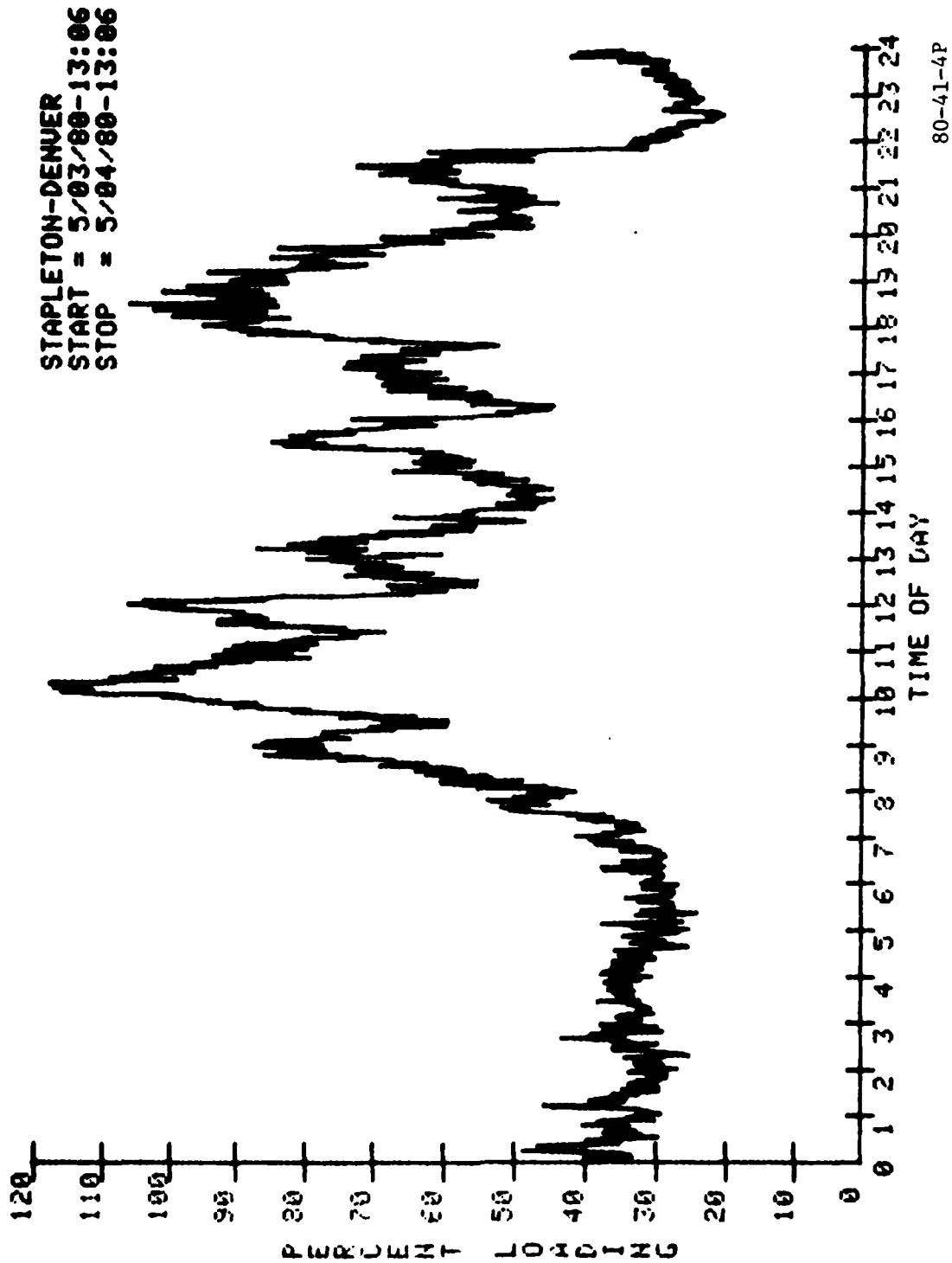


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 16 of 30)

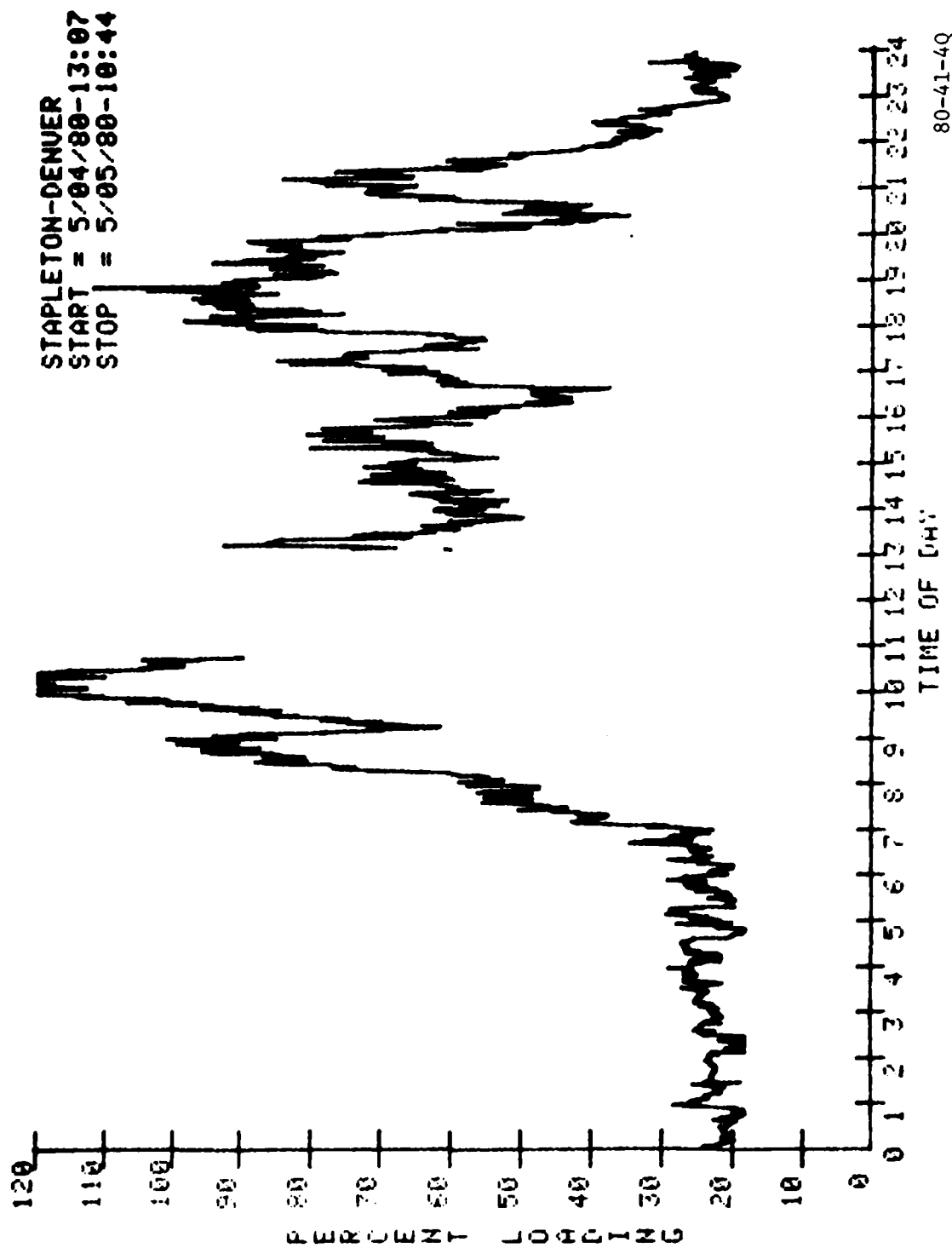
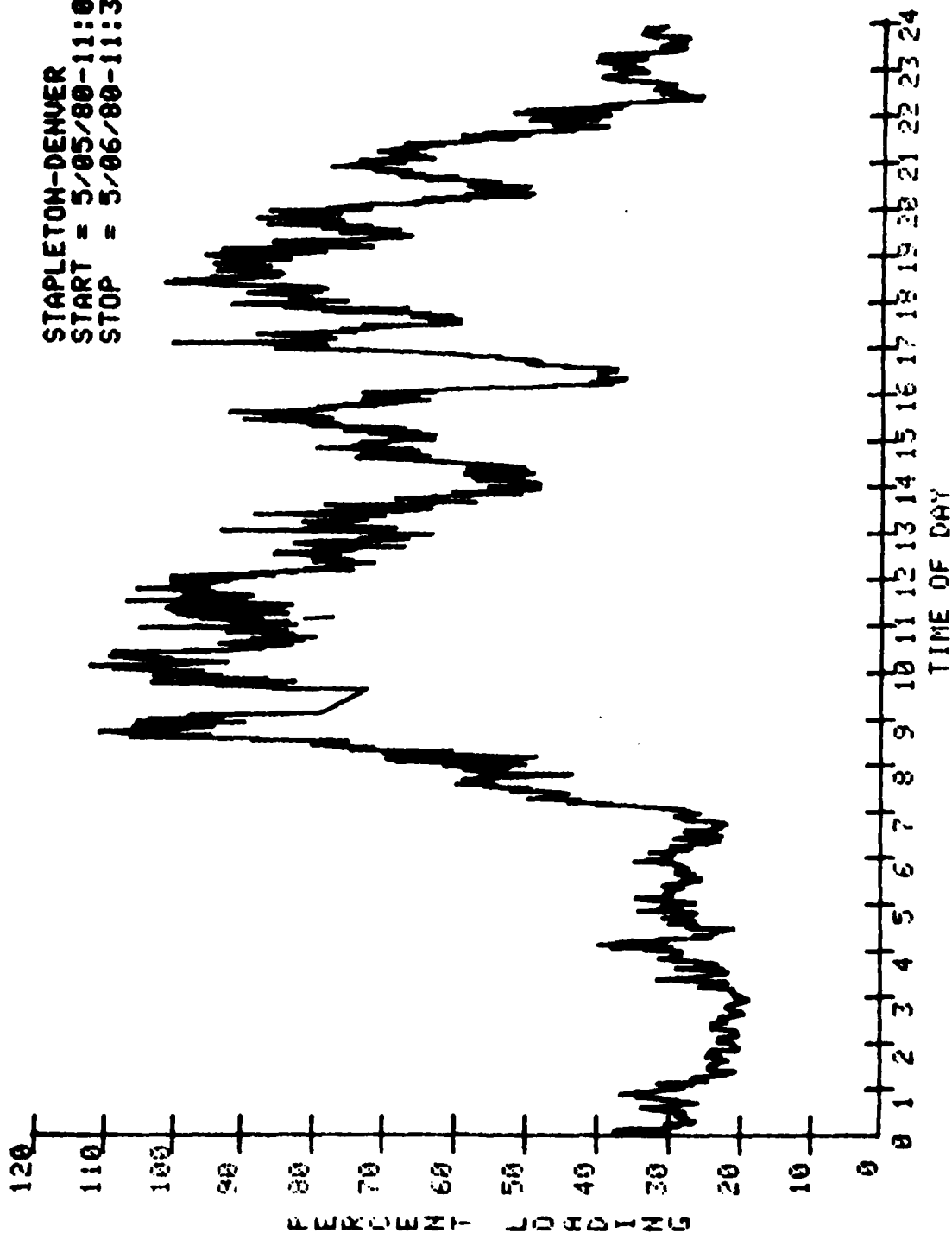


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 17 of 30)

STAPLETON-DENVER
 START = 5/05/80-11:00
 STOP = 5/06/80-11:37



80-41-4R

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 18 of 30)

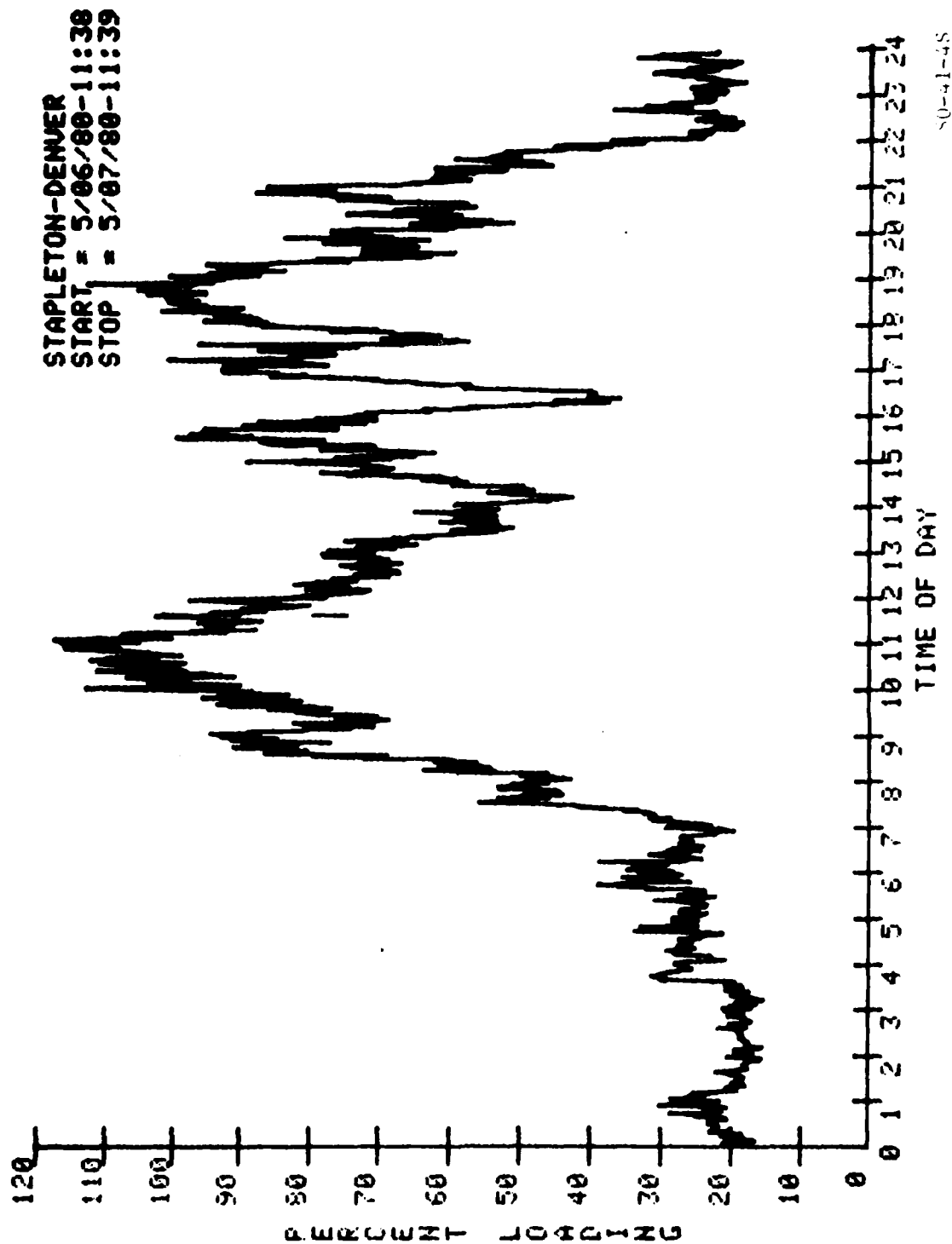
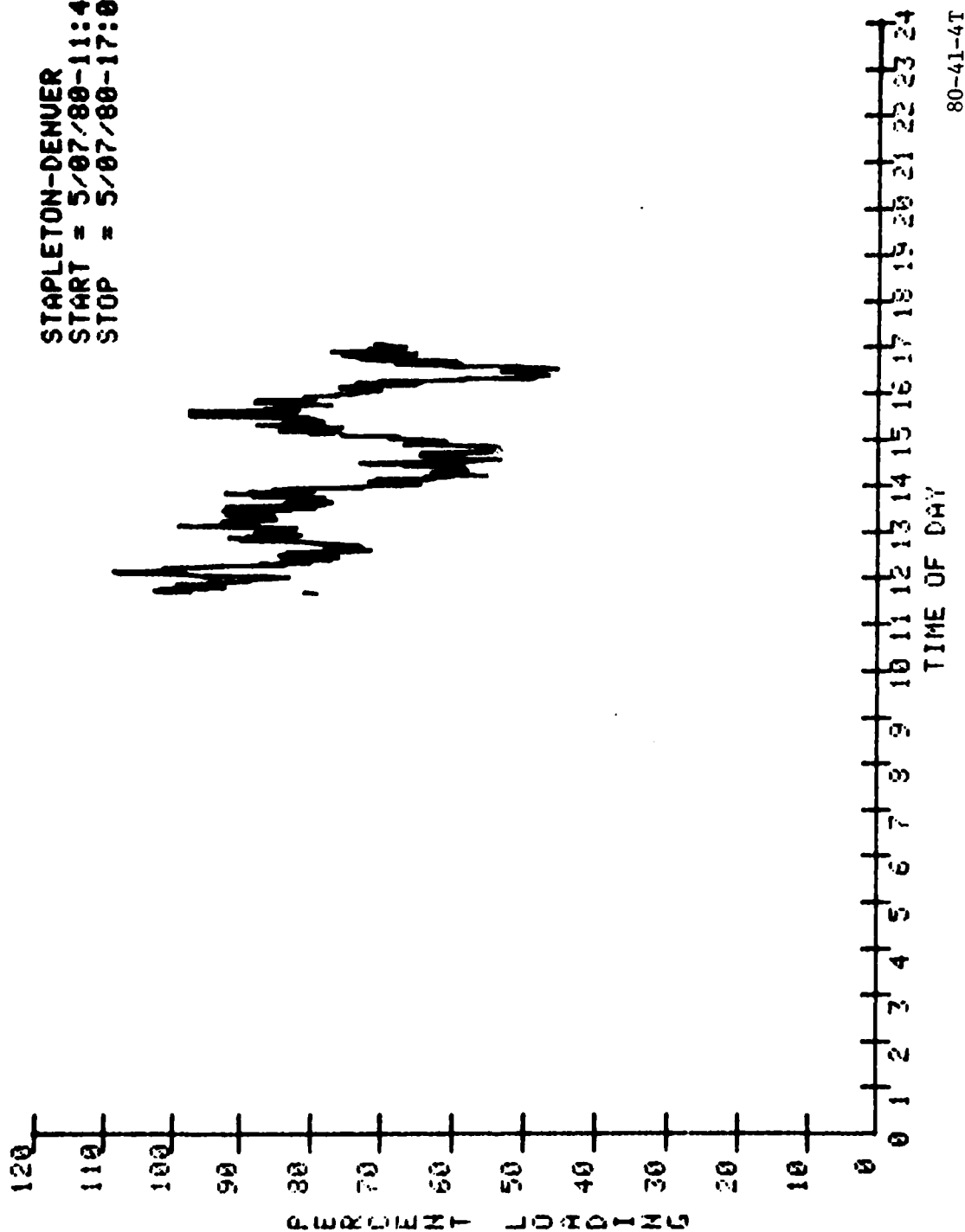


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 19 of 30)

STAPLETON-DENVER
 START = 5/07/80-11:40
 STOP = 5/07/80-17:04



80-41-4T

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 20 of 30)

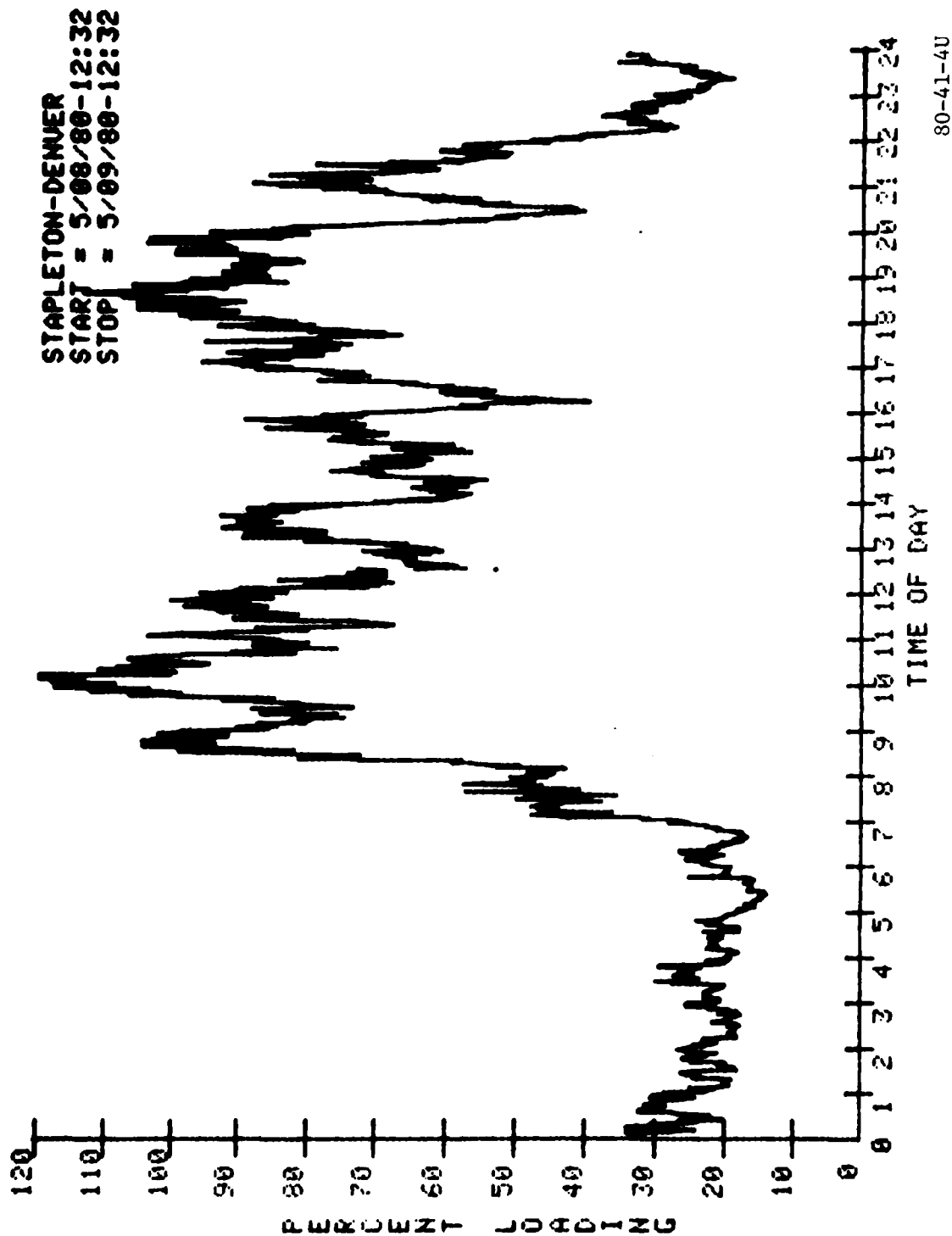
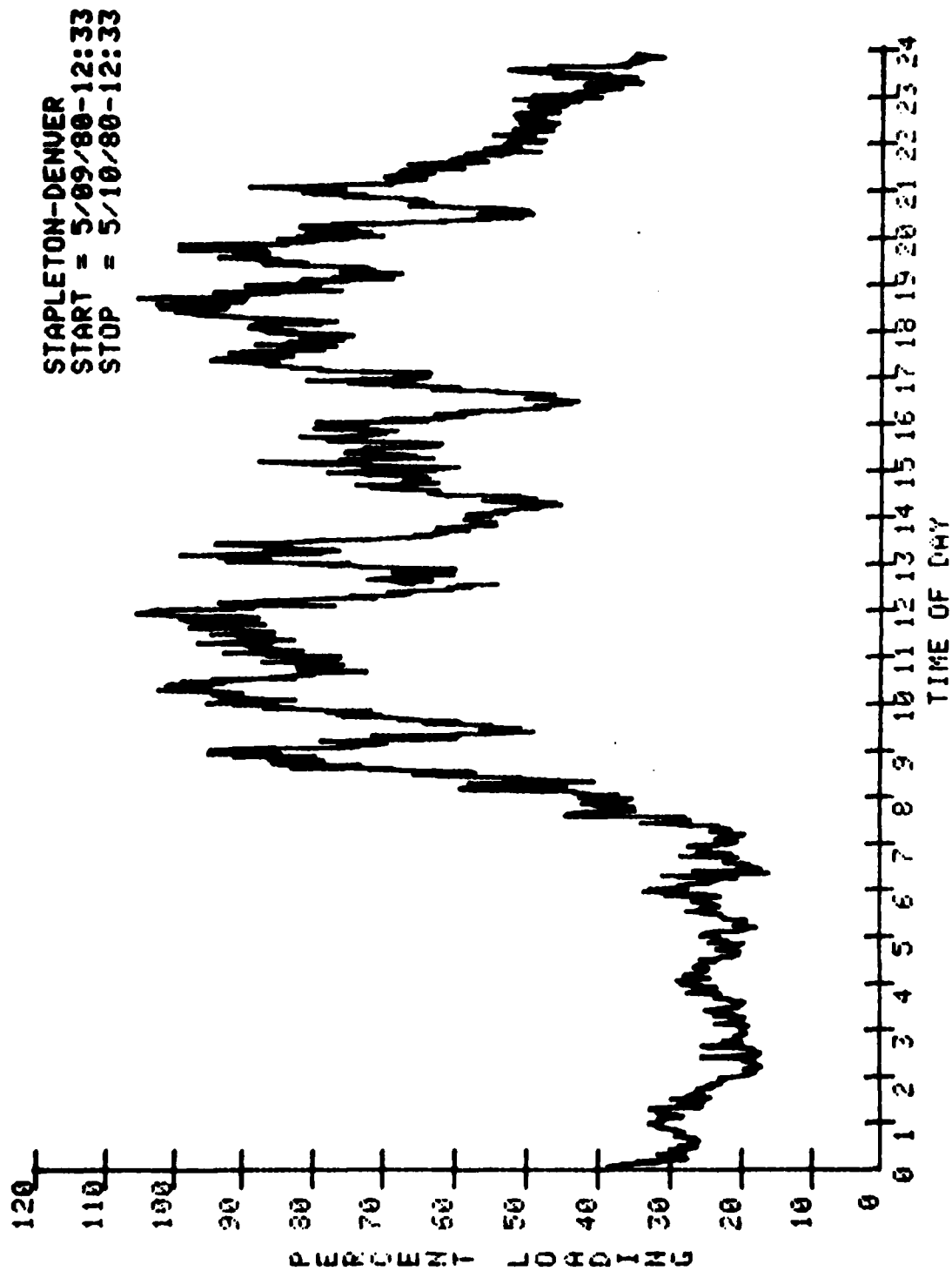


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 21 of 30)



80-41-4V

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 22 of 30)

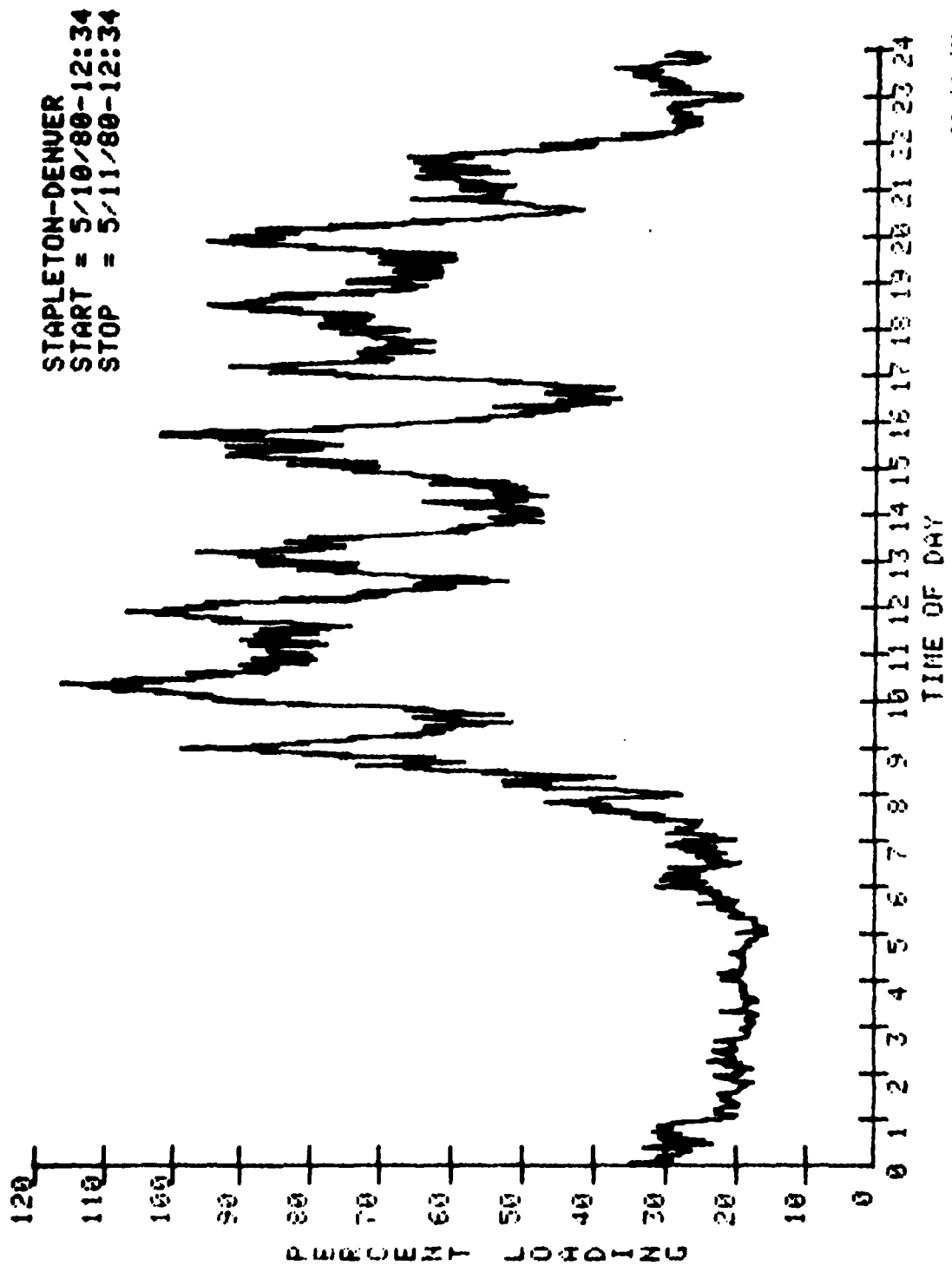


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 23 of 30)

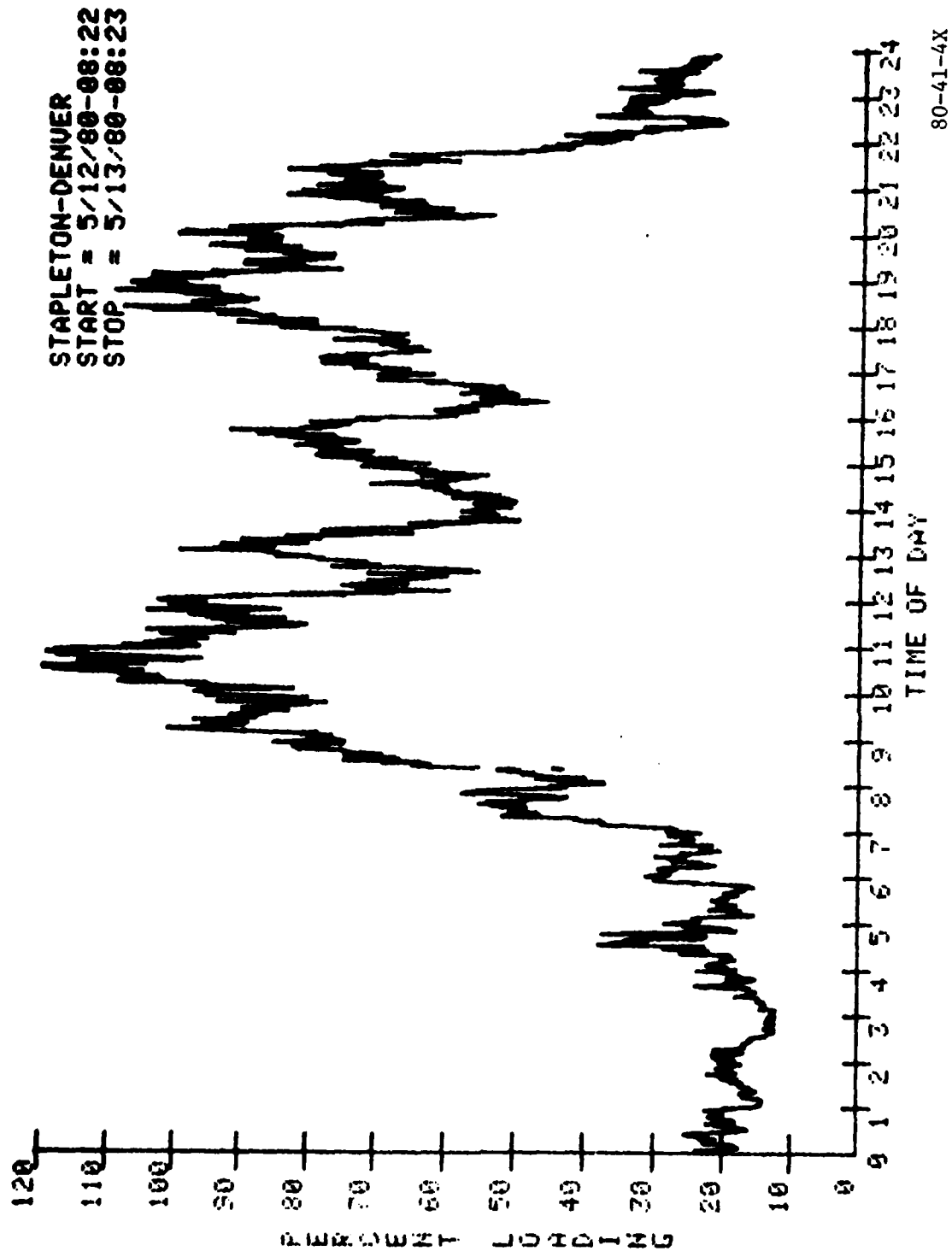


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 24 of 30)

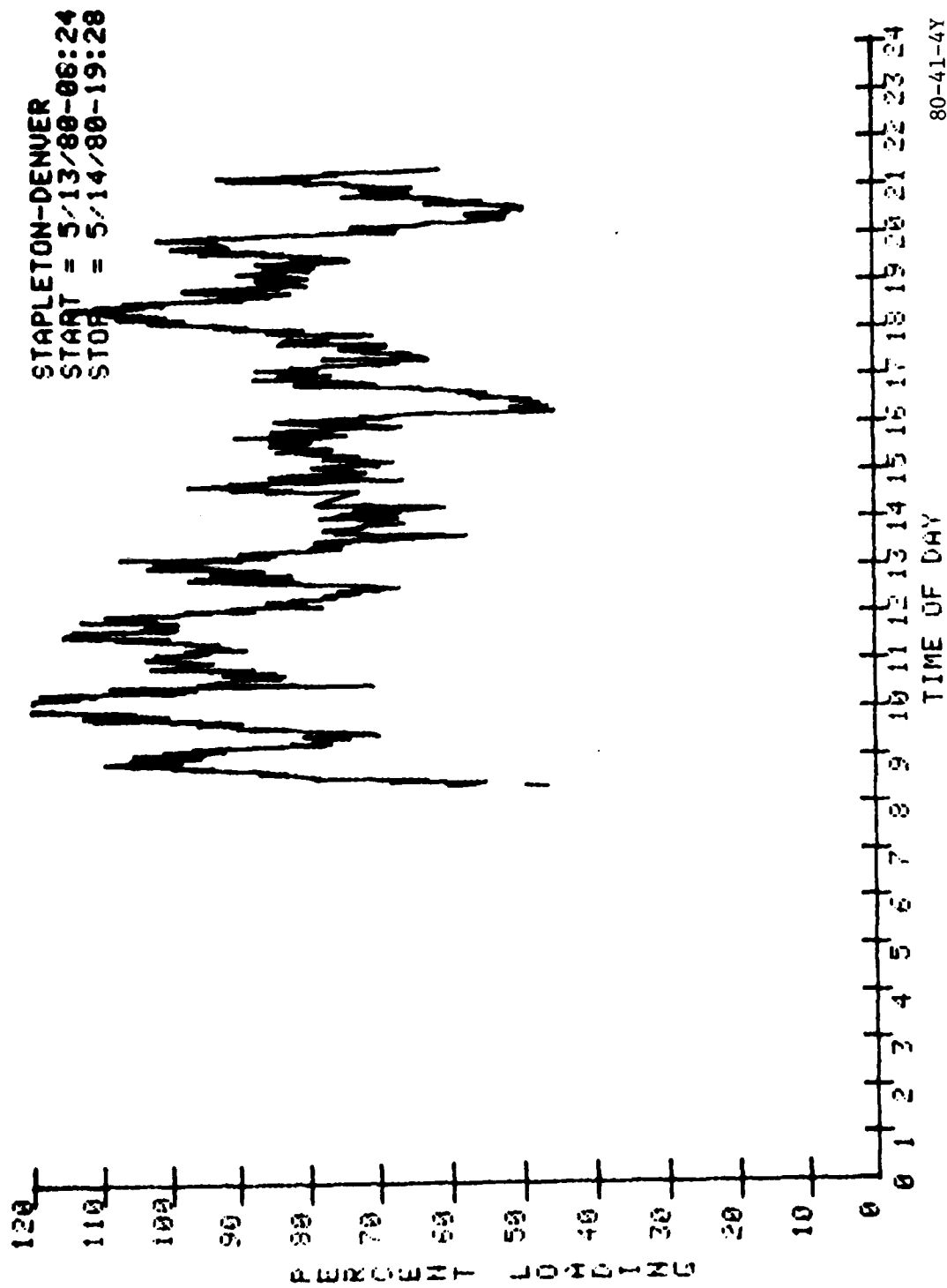


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 25 of 30)

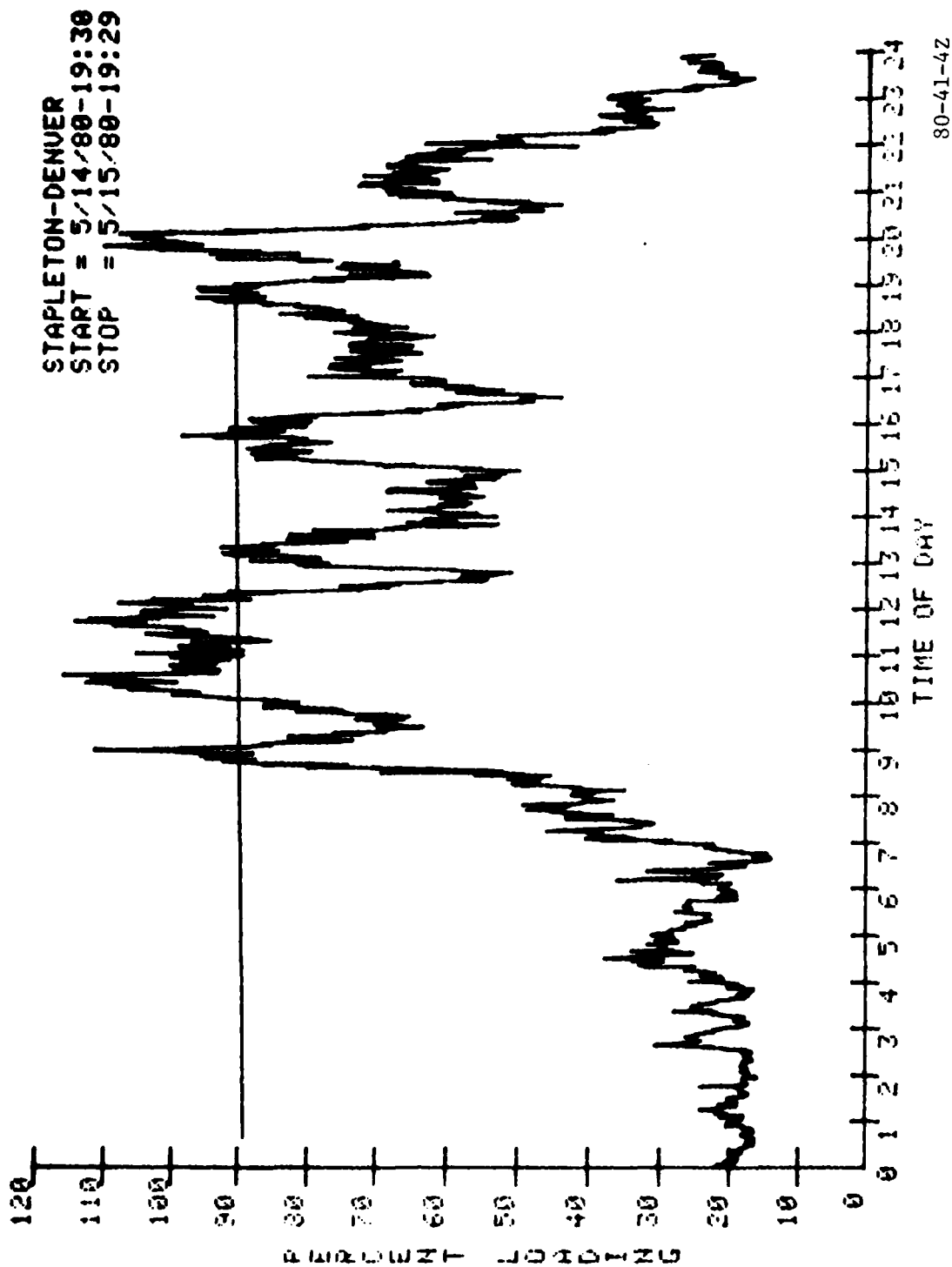


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 26 of 30)

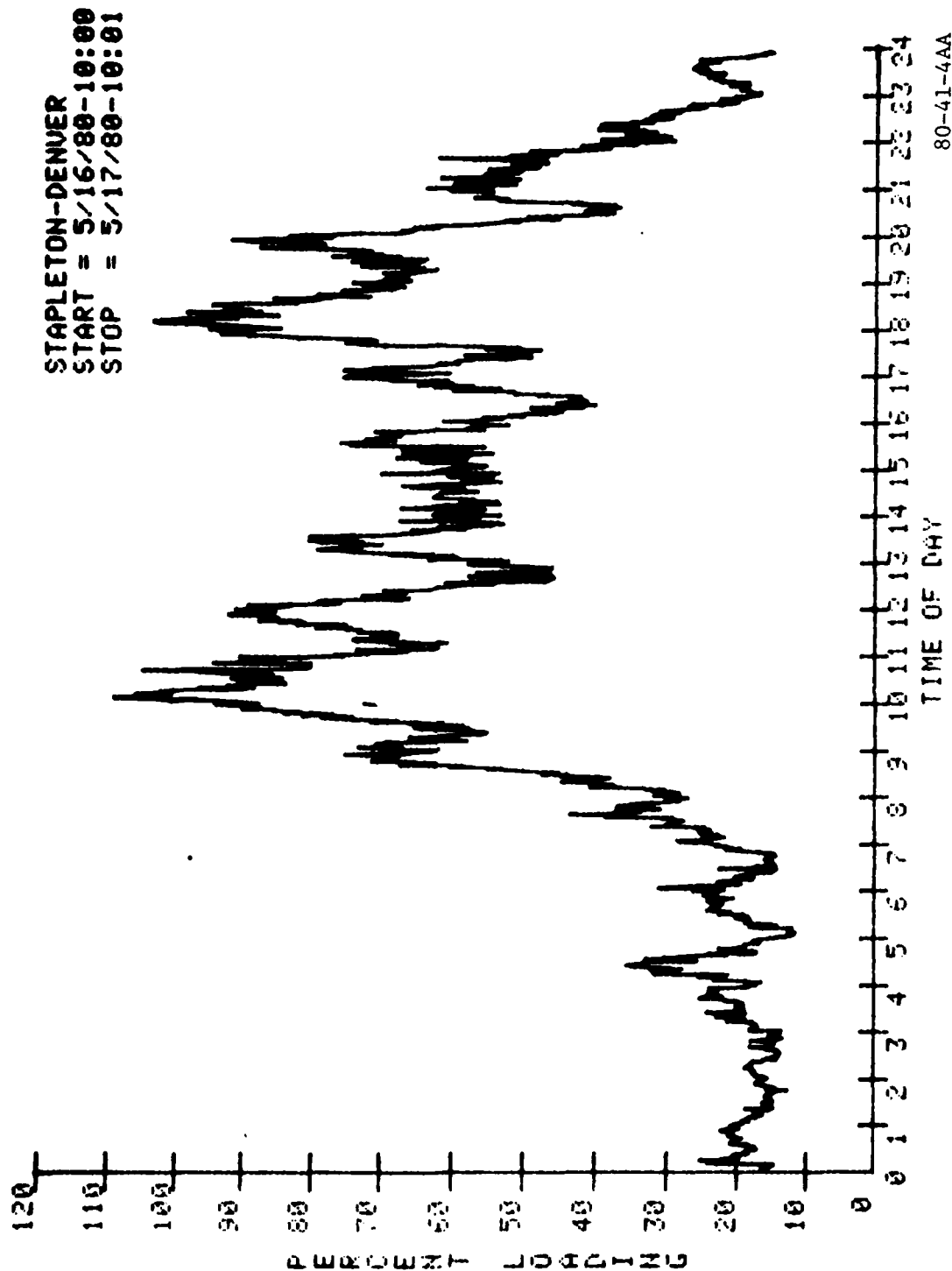
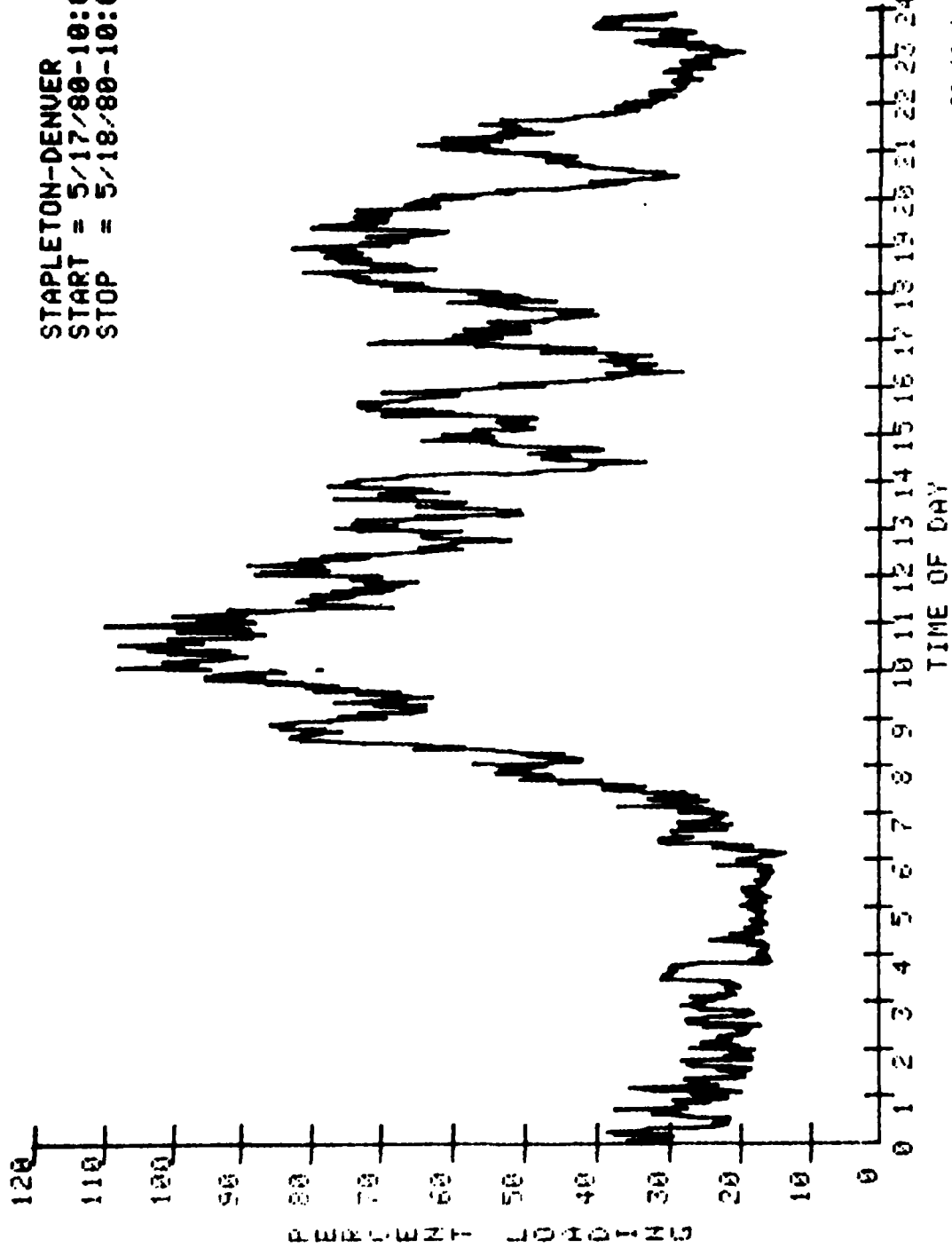


FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 27 of 30)

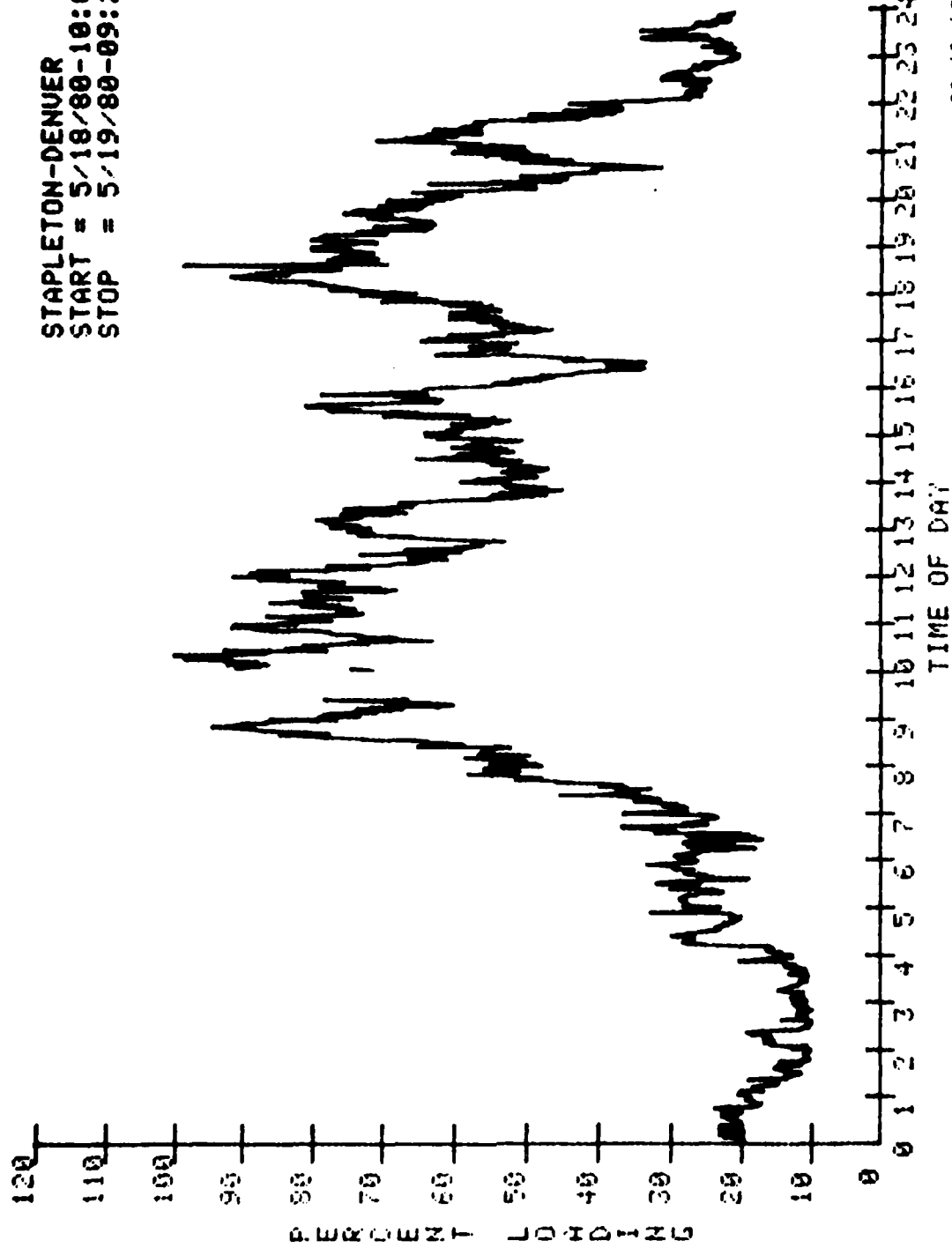
STAPLETON-DENVER
 START = 5/17/88-10:02
 STOP = 5/18/88-10:02



80-41-4BB

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 28 of 30)

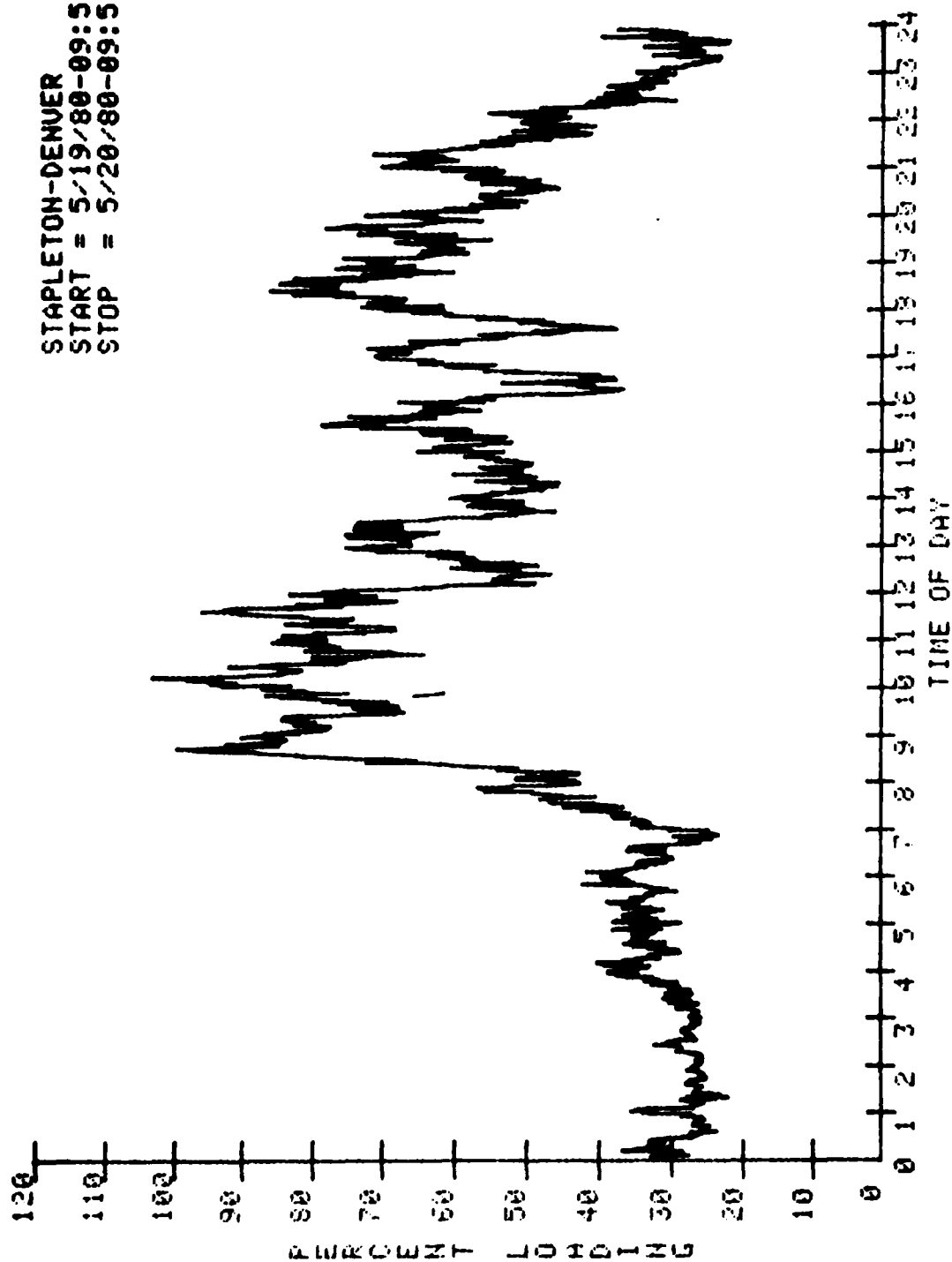
STAPLETON-DENVER
 START = 5/18/80-10:03
 STOP = 5/19/80-09:26



80-41-4CC

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 29 of 30)

STAPLETON-DENVER
 START = 5/19/80-09:51
 STOP = 5/20/80-09:51



80-41-4DD

FIGURE 4. MEASURED INTERROGATION RATE DENVER, COLORADO (Sheet 30 of 30)

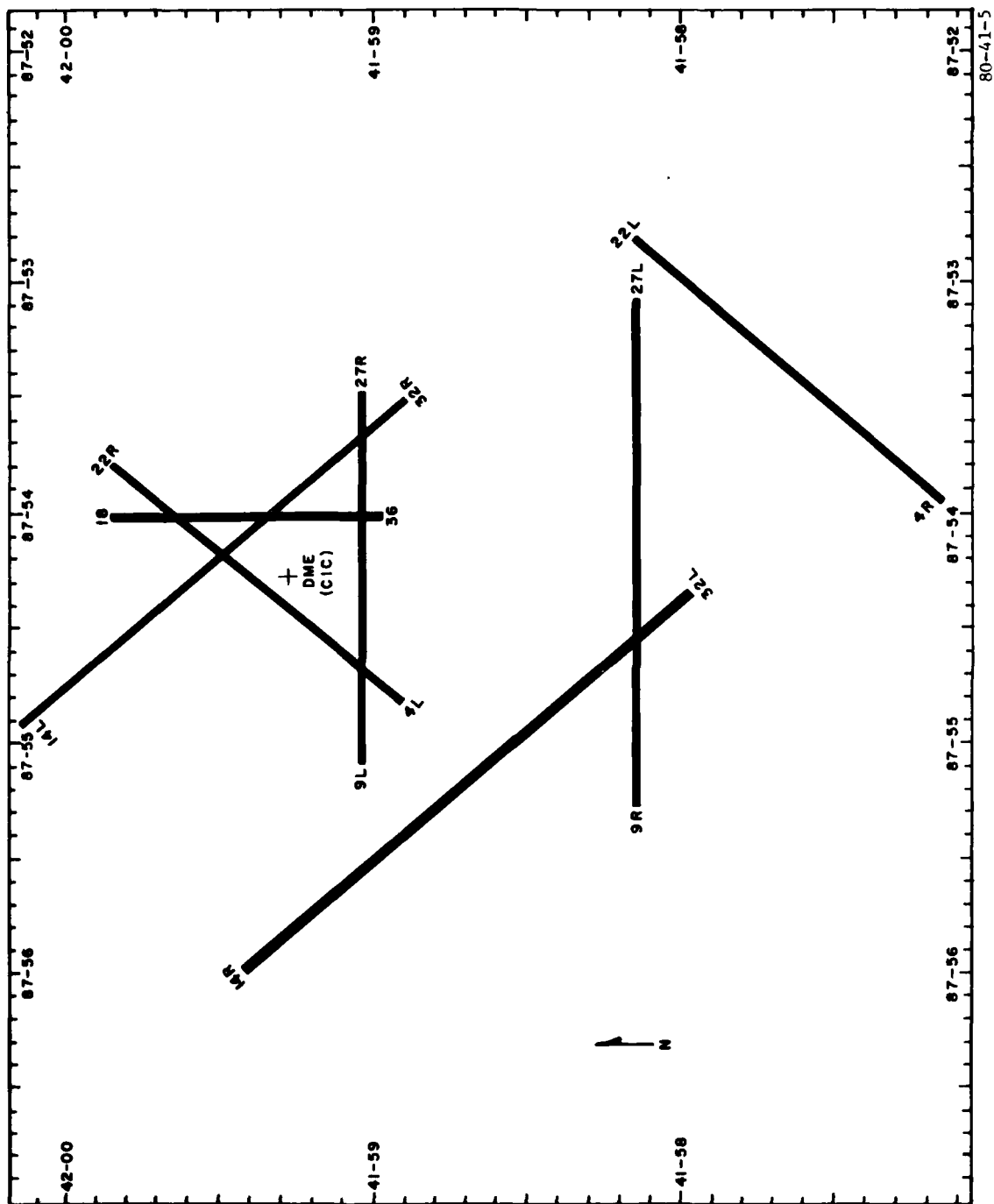


FIGURE 5. AIRPORT MAP CHICAGO, ILLINOIS

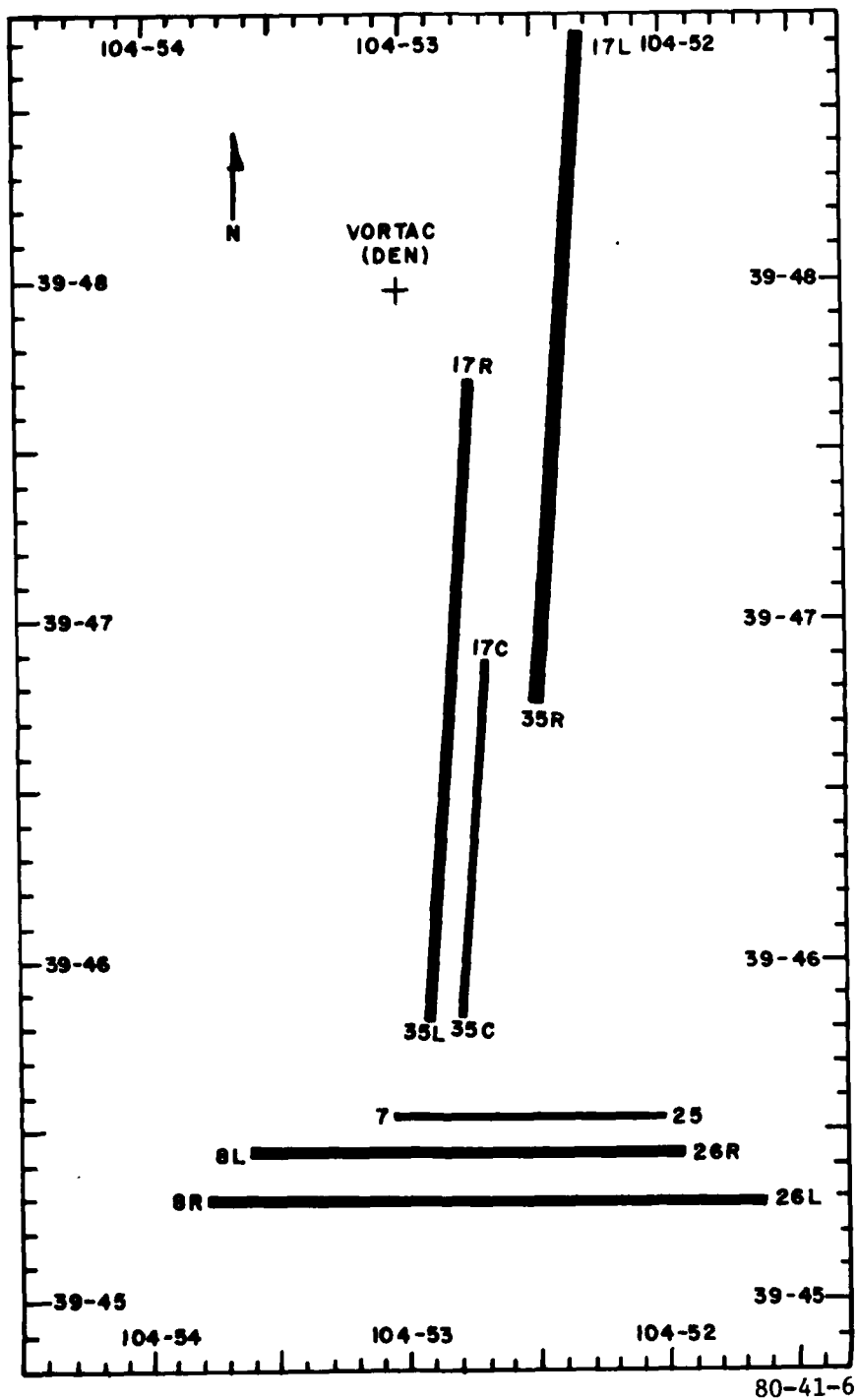


FIGURE 6. AIRPORT MAP DENVER, COLORADO